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JAMES RIVER-WILSON CREEK STUDY, SPRINGFIELD, MISSOURI. VOLUME II

Robert S. Kerr Water Research Center
Ada, Oklahoma

June 1969

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WILSON CREEK STUDY
SPRINGFIELD, MISSOURI

U.S. Department of the Interior
Federal Water Pollution Control Administration
Robert S. Kerr Water Research Center
Technical Services Program
Ada, Oklahoma
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Volume II

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FWPCA PROJECT PERSONNEL

Richard Duty, Chief, Technical Services Program

Bruce R. Barrett, Sanitary Engineer and Project Director

Baptiste B. Shunatona, Jr., Geologist

Jim D. Millsap, Engineering Technician

Grady Campbell, Engineering Technician

Ralph E. (Ted) Austin, Aquatic Biologist

David N. Peters, Aquatic Biologist

Robert E. Crowe, Supervisory Chemist

Bobby G. Benefield, Chemist

Larry Streck, Chemist

Clarence Edmonson, Chemist

Jim Westhoff, Chemist

Harold Cumiford, Microbiologist

John Matthews, Aquatic Biologist

Billy Colbert, Biological Aide

Donald Pherigo, Engineering Aide

Ralph Harkins, Statistician

Jim Kingery, Statistician

Lan Vandeveer, Draftsman

Dorothy R. Baker, Secretary

Chursey Fountain, Secretary

Nancy Marlow, Secretary

Carrie Wood, Secretary

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IN BLACK AND WHITE

JAMES RIVER-WILSON CREEK STUDY
Springfield, Missouri

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MONITOR STRIP CHART RECORDS

JAMES RIVER-WILSON CREEK STUDY
Springfield, Missouri

APPENDIX A

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PHYSICAL AND CHEMICAL METHODS

Hydrological Methods

Determination of the rate of flow (discharge) at the time of sampling was made by the U. S. Geological Survey, Rolla, Missouri. On Wilson Creek at the north edge of the national park (monitor location, Station 27) and on the James River near Nixa (just below Station 33), water stage from which discharge was determined was obtained from continuous water stage recorders. On the James River at Nelson Mill Bridge (Station 39) and at Bernet Farm (monitor location, Station 41), water stage was obtained from portable, continuous recording gages. Late in the project, the portable gages were moved to the new monitor locations on Wilson Creek above the treatment plant (Station 14) and Rader Spring (Station 25). Prior to the move, water stage which was used to determine discharge at the two sites was obtained from staff gage readings at the time of sampling. Staff gage readings were observed at Rader Sink (Station 23), Terrell Creek at Road ZZ (Station 29), and Wilson Creek at Manley Ford (Station 30). Reference points on bridge railings were used to measure stage for which discharges were determined at Jordan Creek at Bennett Street (Station 8), Wilson Creek at Highway 13 Bypass (Station 12), Wilson Creek at Highway 60 and 166 (Station 13), South Creek at Road FF (Station 20), and Wilson Creek at Rader Bridge (Station 24).

Continuous Water Quality Measurement

The continuous measurement of stream quality was achieved by the use of two monitors manufactured by Fairchild Space and Defense Systems Company.[1] The monitors, mounted in small (8' x 7') enclosed trailers, continuously measure and record dissolved oxygen, temperature, pH, and conductivity.

Preparations for operation include blocking up and leveling of the trailer onto heavy timbers, positioning and securing of a submersible pump in the stream, laying the water supply line and power cable between pump and monitor, hooking into line power, and calibration of the instrument.

The DO parameter was calibrated against the Winkler DO procedure (1) on a sample drawn from the plenum chamber. Calibration intervals vary primarily with the quality of water being monitored and may be as frequent as twice a week in polluted water or as long as every three weeks. DO accuracy and precision is ±0.24 mg/l, and its transient response time is 2 minutes. DO is automatically temperature compensated between 32°F and 125°F.

Temperature is measured by a thermistor with a platinum resistance element. Its accuracy and precision is ±1.0°F and has a maximum transient response time of 2 minutes. Temperature was calibrated against a dial-type laboratory thermometer.

Buffer solutions of pH 7 and 10 were used to calibrate the pH parameter. Its accuracy and precision is ±0.1 units, and it is automatically temperature compensated between 32°F and 125°F.

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[1] The mention of company names and their products does not imply endorsement by the Federal Water Pollution Control Administration.

Conductivity was calibrated against standard solutions of 600 and 1200 μmhos/cm. It is automatically temperature compensated between 32°F and 125°F and has an accuracy and precision of ±24 μmhos/cm.

The monitor strip chart data were validated on the chart paper following each calibration check.

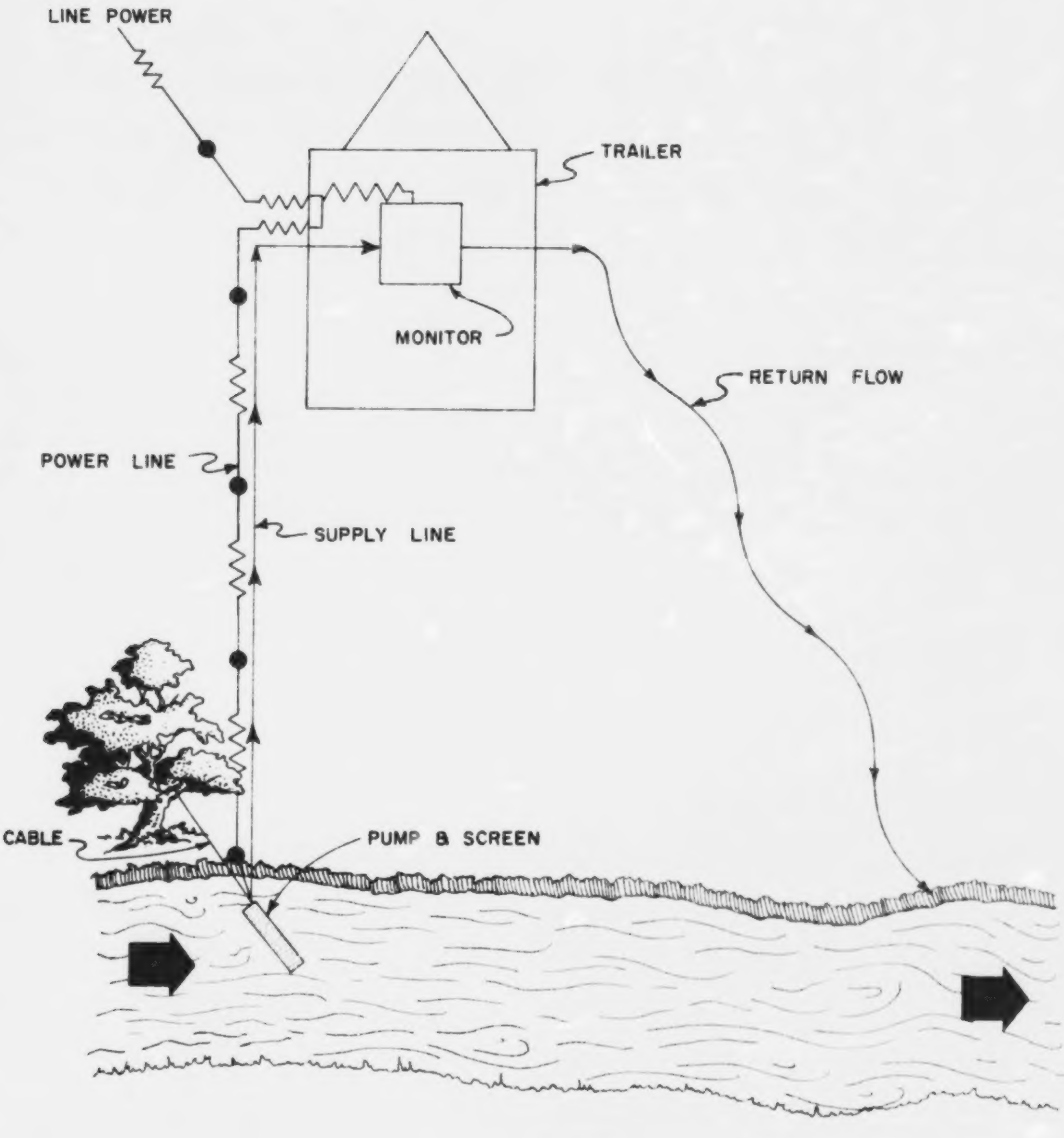
The pump used was a Peerless Dynaflow, 3/4 horsepower, submersible model. The intake screen was removed, and the entire pump was encased in a screening cylinder made of perforated stainless steel. The pump and screen were secured by suspending them in the stream with 1/8-inch diameter cable from an overhanging limb, or in shallow areas by laying the pump and screen in a horizontal position and tying with cable to a nearby tree.

Water is moved from the stream by the pump through a one-inch inside diameter plastic pipe to the monitor. After passing through the flow chamber, the water leaves the trailer by a two-inch plastic pipe and returns to the stream by surface flow. A schematic diagram of the flow pattern is included as Figure A-1.

The flow enters the bottom of the monitor through a plenum chamber, moving upward through funnels screwed into holes in the top of the plenum chamber. Sensors for each of the parameters are suspended in these funnels. Signals generated by the sensors are transmitted to the analyzer-amplifier cubicle, which is of modular design. Following signal conditioning and amplification, signals are transmitted to two readout devices: (1) direct reading panel meters, and

3a

FIGURE A-1
SCHEMATIC DIAGRAM OF FLOW PATTERN TO MONITORS


LINE POWER
TRAILER
MONITOR
RETURN FLOW
POWER LINE
SUPPLY LINE
CABLE
PUMP & SCREEN

(2) a 12-point strip chart recorder. Solid state circuitry is used throughout the monitors. Figure A-2 is a schematic representation of the monitors.

Field Quality Tests

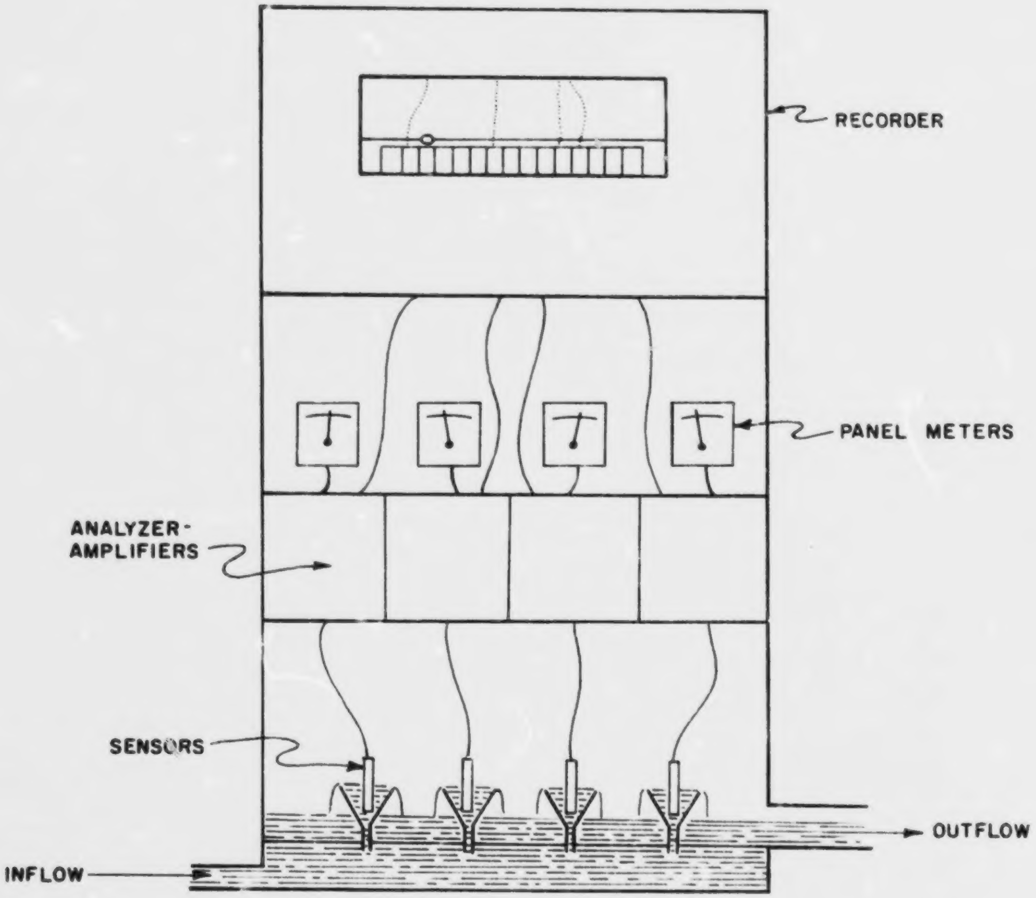
A number of physical and chemical tests were run in the field by the sampling crews. These include dissolved oxygen, temperature, pH, conductivity, and total sulfides. Dissolved oxygen was measured by the Azide Modification of the Winkler Method as shown in *Standard Methods* (1). Water temperature was measured with dial thermometers manufactured by Weston. Measurements of pH were made by portable pH meters of two types. One is made by Analytical Measurements, Inc., and the other by Instrumentation Laboratories, Inc. At times, pH was measured with pH indicating paper with an accuracy of 0.2 units. Beckman conductivity meters were used to measure conductivity. Sulfide was measured by the Pomeroy Method, using a kit made by the La Motte Chemical Company.

Sampling Procedures

Samples for laboratory chemical analyses were grab samples taken from sections of the stream where a downstream current existed. While the samples were essentially surface samples, care was taken to avoid skimming only the top layer of water into the sampling container. This was accomplished by allowing the sampling containers to fall some 6 to 12 inches, where possible, below the water surface. Care was also taken to avoid aeration of the samples.

FIGURE A-2

SCHEMATIC REPRESENTATION OF FAIRCHILD WATER QUALITY MONITORS


RECORDER
PANEL METERS
ANALYZER-AMPLIFIERS
SENSORS
OUTFLOW
INFLOW

Samples for BOD were iced, while other samples were preserved with mercuric chloride. Still others were preserved with sulfuric acid. Samples were flown back to the lab once a day.

Laboratory Quality Control and Analytical Methods

As a result of analyzing duplicates and spiked standards on each eighth and twelfth sample, respectively, a standard deviation for precision and accuracy was obtained for each parameter analyzed. Validation of the data was judged by the comparison of standard deviations obtained on each parameter with that of established references. Based upon these comparisons, the analyses were determined to be reliable.

The procedures outlined in *Standard Methods for the Examination of Water and Wastewater* (1) and the *FWPCA Official Interim Methods for Chemical Analysis of Surface Waters* (2) were used for the chemical analyses of the samples collected on this project. The methods used for all analyses are described as follows:

BOD (5-day, 20°C) - (1), Page 415, modification, 300 ml titration technique.

COD - (1), Page 510.

Nitrate and Nitrite - (2), Page 79, Automated Method A.

Ammonia Nitrogen - (1), Page 187, Method A.

Organic Nitrogen - (2), Page 73.

Sulfate - (2), Page 134.

Total Suspended Solids - (1), Page 246.

Total Phosphate Phosphorus - (1), Page 236, Method C - potassium persulfate digestion modification.

pH - (1), Page 226, glass electrode method.

Metals - (2), atomic absorption.

BIBLIOGRAPHY

1. American Public Health Association, et. al., *Standard Methods for the Examination of Water and Wastewater*, 12th ed., New York, 1965.

2. Federal Water Pollution Control Administration, *FWPCA Official Interim Methods for Chemical Analysis of Surface Waters*, September 1968.

RAW DATA

Field and Laboratory Determinations of Flow and Water Quality

Intensive Sampling Phase

STATION 1 - Frisco discharge at end of culvert under railroad tracks adjacent to south edge of private (Frisco) road extending east from Division Street

Date 1968	Time CDT	Q cfs	D.O. mg/1	Temp. °F	pH	Cond. µmho/cm at 25°C	BOD mg/1	COD mg/1	NO_3-N mg/1	NO_2-N mg/1	NH_3-N mg/1	Org.N mg/1	PO_4-P mg/1
7-20	1:30 pm	1.0	0.0	90	7.0	800	48	138	<.1	<.005	.3	3.4	0.0
7-21	9:00 am	2.0	0.0	81	8.2	860	54	146	.1	<.005	.3	3.2	.9
7-21	2:25 pm	2.5	0.0	87	8.4	825	53	176	<.1	<.005	.2	2.9	1.2
7-22	1:25 pm	1.0	0.0	92	9.2	760	48	180	<.1	.010	.3	1.3	1.0
7-23	9:30 am	1.0	0.0	83	9.0	640	88	175	<.1	<.005	.5	2.9	.6
7-23	2:00 pm	1.0	0.0	90	7.2	825	43	143	<.1	<.005	.3	1.9	.5
Dry Weather Average		1.4	0.0	87	8.2	785	56	160	<.1	<.005**	.3	2.6	.7
7-28	2:55 pm	1.0	0.0	-	9.5	800	53	147	<.1	<.005	.3	2.1	1.4
7-29	9:40 am	0.5	0.1	77	8.5	700	50	133	<.1	<.005	.4	2.4	1.2
7-29	1:30 pm	1.0	0.0	84	8.3	750	30	128	.1	<.005	.5	1.5	1.6
7-30	9:40 am	0.5	-	75	8.5	800	48	106	<.1	<.005	.8	1.1	1.3
7-30	1:25 pm	2.0	0.0	81	-	650	66	178	.1	<.005	1.8	1.2	2.3
7-31	8:45 am	0.5	0.0	76	7.4	530	533	193	-	<.005	.5	1.5	-
7-31	12:50 pm	1.0	0.0	82	8.6	740	51	174	<.1	<.005	.7	1.8	1.6
Wet Weather Average		0.9	0.0	79	8.5	710	119	151	<.1	<.005**	.7	1.7	1.6
Overall Average		1.2	0.0	83	8.3	745	90	155	<.1	<.005**	0.5	2.1	1.2

** Approximation

STATION 3 - MFA Plant Foods discharge

Date 1968	Time CDT	Q cfs	D.O. mg/l	Temp. °F	pH	Cond. μmho/cm at 25°C	BOD mg/l	COD mg/l	NO_3-N mg/l	NO_2-N mg/l	NH_3-N mg/l	Org.N mg/l	PO_4-P mg/l
7-20	2:10 pm	No discharge											
7-21	am	No discharge											
7-21	pm	No discharge											
7-22	pm	No discharge											
7-23	am	No discharge											
7-23	pm	No discharge											
Dry Weather Average		None											
7-29	9:05 am	0.1	0.3	75	2.5	5000	<25	51	9.0	<.005	-	-	5.5
7-29	1:00 pm	-	1.9	79	2.8	6000	<25	56	6.5	<.005	-	-	5.2
7-30	10:00 am	0.1	6.8	76	2.1	6000	<25	48	15.8	<.005	306	8.0	36.0
7-30	1:00 pm	-	4.0	77	-	4000	<25	43	18.5	<.005	279	2.0	34.0
7-31	9:20 am	0.6	1.3	76	2.5	4900	<25	40	20.5	<.005	-	-	210.0
7-31	12:20 pm	0.1	4.6	86	3.0	5000	<25	45	18.0	<.005	232.0	18.0	230.0
Wet Weather Average		0.2	3.2	78	2.6	5150	<25	47	14.7	<.005**	272.	9.3	86.8
Overall Average		0.2	3.2	78	2.6	5150	<25	47	14.7	<.005**	272.	9.3	86.8

** Approximation

STATION 8 - Jordan Creek at Bennett Street

Date 1968	Time CDT	Q cfs	D.O. mg/l	Temp. °F	pH	Cond. µmho/cm at 25°C	BOD mg/l	COD mg/l	NO_3-N mg/l	NO_2-N mg/l	NH_3-N mg/l	Org.N mg/l	PO_4-P mg/l
7-20	2:50 pm	-	6.5	83	6.7	430	20	19	.1	<.005	.2	.6	.4
7-21	9:30 am	7.2	4.4	76	6.6	470	5	18	.2	<.005	.2	.8	.3
7-21	3:30 pm	4.3	6.9	81	7.5	540	<5	21	.1	<.005	.2	.6	.4
7-22	2:20 pm	4.3	6.0	86	7.6	430	<5	70	.1	<.005	.3	1.2	.5
7-23	9:45 am	4.3	3.8	78	8.8	320	7	50	.1	<.005	.1	.8	.2
7-23	1:15 pm	2.5	3.6	82	6.4	380	5	27	.2	<.005	.2	.7	.2
Dry Weather Average		4.5	5.2	81	7.3	428	7**	34	.1	<.005**	.2	.8	.3
7-28	4:00 pm	<1.0	5.5	77	8.3	600	<5	31	.9	<.005	.3	.6	.5
7-29	10:05 am	7.2	5.7	72	7.3	420	<5	19	.7	<.005	.3	.4	.4
7-29	2:40 pm	10.0	7.0	77	7.6	640	<5	14	.8	<.005	.3	.2	.3
7-30	10:25 am	6.2	6.0	72	7.0	530	<5	10	.6	<.005	.8	.4	1.1
7-30	2:00 pm	1300.*	7.5	72	-	240	9	84	.6	<.005	.2	1.9	.7
7-31	10:00 am	10.5	4.9	73	6.2	460	<5	16	2.0	<.005	1.0	.9	.8
7-31	1:15 pm	7.2	5.3	79	7.2	675	<5	16	2.0	<.005	.9	<.1	.6
Wet Weather Average		7.0*	6.0	75	7.3	509	<5**	27	1.1	<.005**	.5	.6	.6
Overall Average		6.0*	5.6	78	7.3	472	6**	30	0.6	<.005**	.4	.7	.5

* Average does not include heavy runoff
** Approximation

STATION 10 - Hoffman-Taff discharge
(composite of cooling water discharges)

Date 1968	Time CDT	Q cfs	D.O. mg/1	Temp. °F	pH	Cond. µmho/cm at 25°C	BOD mg/1	COD mg/1	NO_3-N mg/1	NO_2-N mg/1	NH_3-N mg/1	Org.N mg/1	PO_4-P mg/1
7-20	3:10 pm	0.04	6.8	70	5.0	310	16	30	<.1	<.005	<.1	.7	.1
7-21	9:40 am	0.09	-	69	7.6	270	10	14	.1	<.005	.1	.1	.1
7-21	3:40 pm	0.1	-	64	7.4	330	<5	13	<.1	<.005	<.1	<.1	.1
7-22	2:30 pm	0.4	6.8	71	7.4	310	10	26	<.1	<.005	.2	.2	.1
7-23	9:55 am	0.12	6.5	77	8.4	345							
7-23	1:30 pm	0.1	6.0	73	7.5	320	>81	106	<.1	<.005	.2	.9	.2
Dry Weather Average		0.14	6.5	71	7.2	314	24**	38	<.1	<.005**	0.1**	.4**	.1
7-28		No run											
7-29	am	No run											
7-29	2:45 pm	0.2	6.4	75	7.2	330	23	34	<.1	<.005	.1	.5	.2
7-30	am	No run											
7-30	pm	No run											
7-31	am	No run											
7-31	pm	No run	—	—	—	—	—	—	—	—	—	—	—
Wet Weather Average		0.2	6.4	75	7.2	330	23	34	<.1	<.005**	.1	.5	.2
Overall Average		0.15	6.5	72	7.2	317	24**	37	<.1	<.005**	.1**	.4**	.1

** Approximation

STATION 10A - Hoffman-Taff discharge between railroad tracks and plant

Date 1968	Time CDT	Q cfs	D.O. mg/1	Temp. °F	pH	Cond. µmho/cm at 25°C	BOD mg/1	COD mg/1	NO_3-N mg/1	NO_2-N mg/1	NH_3-N mg/1	Org.N mg/1	PO_4-P mg/1
7-20	3:50 pm	0.5	6.8	82	6.6	290	<25	<4	<.1	<.005	<.1	.2	.3
7-21	10:00 am	1.0	-	76	7.0	320	<25	4	<.1	<.005	.1	.6	.3
7-21	3:20 pm	0.5	-	82	7.8	280	< 5	10	<.1	<.005	.1	.2	.3
7-22	3:00 pm	0.5	3.1	85	8.2	320	< 5	18	.1	<.005	.3	1.1	.3
7-23	10:25 am	0.5	5.0	84	8.2	300	<25	30	.4	<.005	.3	.9	.3
7-23	12:45 pm	2.0	7.0	82	7.0	320	<25	5	<.1	<.005	.1	.2	.1
Dry Weather Average		0.8	5.5	82	7.5	305	<25	12**	.1**	<.005**	.1**	.5	.3
7-28	am	No run											
7-29	am	No run											
7-29	2:25 pm	0.5	7.8	75	8.2	370	<25	8	<.1	<.005	.1	.2	.2
7-30	am	No run											
7-30	pm	No run											
7-31	am	No run											
7-31	pm	No run											
Wet Weather Average		0.5	7.8	75	8.2	370	<25	8	<.1	<.005**	.1	.2	.2
Overall Average		0.8	5.9	81	7.6	314	<25	11**	0.1**	<.005**	.1**	.5	.2

** Approximation

STATION 10B - Hoffman-Taff discharge just below railroad tracks

Date 1968	Time CDT	Q cfs	D.O. mg/1	Temp. °F	pH	Cond. µmho/cm at 25°C	BOD mg/1	COD mg/1	NO_3-N mg/1	NO_2-N mg/1	NH_3-N mg/1	Org.N mg/1	PO_4-P mg/1
7-20	3:35 pm	0.25	1.6	77	6.5	520	11	17	.2	<.005	.4	1.3	.2
7-21	10:15 am	0.01	-	72	6.6	600	<25	29	.2	<.005	1.0	1.5	.5
7-21	3:00 pm	0.1	1.5	75	6.5	600	<25	35	.2	<.005	1.1	1.6	.1
7-22	2:50 pm	0.1	5.2	79	7.0	560	<25	30	.4	<.005	1.7	2.7	.1
7-23	10:10 am	0.2	3.8	74	8.2	200	<25	48	.4	<.005	.3	1.7	.3
7-23	12:50 pm	0.1	2.0	78	6.2	625	19	28	.2	<.005	1.7	1.2	0.0
Dry Weather Average		0.1	2.8	76	6.8	518	<25	31	.3	<.005**	1.0	1.7	.2
7-28	am	No run											
7-29	am	No run											
7-29	2:15 pm	0.1	4.2	72	7.2	550	53	24	.4	<.005	1.0	.9	.1
7-30	am	No run											
7-30	pm	No run											
7-31	am	No run											
7-31	pm	No run											
Wet Weather Average			4.2	72	7.2	550	53	24	.4	<.005**	1.0	.9	.1
Overall Average		0.1	3.0	75	6.9	523	25**	30	.3	<.005**	1.0	1.5	.2

** Approximation

STATION 11 - Fassnight Creek about 1/4 mile
below Glenstone Avenue (near corner
of Weller Street and Bennett Street)

Date 1968	Time CDT	Q cfs	D.O mg/1	Temp. °F	pH	Cond. µmho/cm at 25°C	BOD mg/1	COD mg/1	NO_3-N mg/1	NO_2-N mg/1	NH_3-N mg/1	Org.N mg/1	PO_4-P mg/1
7-21	8:30 am	0.5	6.1	81	7.0	475	7	17	.2	<.005	.1	.8	.7
7-21	1:55 pm	1.0	6.6	86	8.2	330	6	25	.3	<.005	.2	.6	3.6
7-22	1:40 pm	0.5	6.1	89	7.5	370	7	18	.4	<.005	.3	.3	1.5
7-23	11:00 am	1.0	6.2	87	8.0	500	<5	10	.6	<.005	.2	.2	.8
7-23	1:15 pm	1.5	6.3	86	7.3	390	8	10	.5	<.005	.7	.2	.8
Dry Weather Average		0.9	6.3	86	7.6	413	6**	16	.4	<.005**	.3	.4	1.5
7-28	4:35 pm	1.0	6.2	86	8.6	620	<5	12	.1	<.005	.1	.1	.9
7-29	9:00 am	1.0	7.1	79	7.2	425	<5	6	.2	<.005	.1	.4	.6
7-29	1:35 pm	2.0	6.8	86	7.5	390	<5	14	.3	<.005	<.1	.5	1.0
7-30	8:00 am	0.5	6.6	82	7.8	340	<5	10	.4	<.005	.1	.9	.7
7-30	12:35 pm	7.0	6.3	81	7.4	1500	<5	20	.4	<.005	<.1	.6	1.1
7-31	9:40 am	0.5	6.2	81	6.4	425	<5	7	.6	<.005	.3	.9	.9
7-31	pm	No run	—	—	—	—	—	—	—	—	—	—	—
Wet Weather Average		2.0	6.5	83	7.5	616	<5	12	.3	<.005**	.1**	.6	.9
Overall Average		1.5	6.4	84	7.5	524	5**	14	.4	<.005**	.2**	.5	1.1

** Approximation

STATION 12 - Wilson Creek at Highway 13

Date 1968	Time CDT	Q cfs	D.O mg/1	Temp. °F	pH	Cond. µmho/cm at 25°C	BOD mg/1	COD mg/1	NO_3-N mg/1	NO_2-N mg/1	NH_3-N mg/1	Org.N mg/1	PO_4-P mg/1
7-20	4:30 pm	5.6	15.6	85	6.9	420	7	12	.7	<.005	.1	.4	.2
7-21	8:45 am	5.8	5.4	76	6.6	500	<5	7	.8	<.005	.1	.4	.2
7-21	2:00 pm	5.0	14.0	79	7.4	460	<5	15	.8	<.005	.1	.4	.3
7-22	3:15 pm	5.8	6.8	86	7.6	420	<5	49	.2	<.005	.7	.3	.3
7-23	9:15 am	5.8	3.5	79	8.4	325	<5	32	.2	<.005	.2	.9	.2
7-23	2:30 pm	5.8	7.6	85	8.0	380	6	34	.3	<.005	.2	.8	.2
Dry Weather Average		5.6	8.8	82	7.5	418	5**	25	.5	<.005**	.2	.5	.2
7-28	3:45 pm	5.8	6.2	77	9.0	550	<5	20	.8	<.005	.1	1.0	.3
7-29	10:25 am	5.8	6.5	73	7.2	500	<5	12	1.2	<.005	<.1	.9	.3
7-29	1:50 pm	5.6	8.6	70	7.7	640	20	12	1.3	<.005	<.1	.7	.4
7-30	9:20 am	5.0	7.0	71	7.6	500	<5	12	1.4	<.005	<.1	.4	.3
7-30	1:40 pm	110.0	7.5	70	-	470	<5	33	2.0	<.005	.4	1.2	.4
7-31	10:20 am	12.0	5.2	73	7.6	420	<5	17	2.2	<.005	.2	1.3	.5
7-31	1:00 pm	7.5	5.7	82	7.3	600	<5	16	2.4	<.005	.5	.5	.4
Wet Weather Average		7.0*	6.7	74	7.7	526	<5**	17	1.6	<.005**	0.2**	.9	.4
Overall Average		6.0*	7.7	78	7.6	476	5**	21	1.1	<.005**	0.2**	.7	.3

* Average does not include heavy runoff

** Approximation

STATION 13 - Wilson Creek at
Highways 60 and 66

Date 1968	Time CDT	Q cfs	D O mg/1	Temp. °F	pH	Cond. µmho/cm at 25°C	BOD mg/1	COD mg/1	NO_3-N mg/1	NO_2-N mg/1	NH_3-N mg/1	Org.N mg/1	PO_4-P mg/1
7-20	5:00 pm	2.8	12.3	81	6.9	450	7	8	.1	<.005	.1	.3	.2
7-21	8:20 am	13.0	5.0	76	6.8	500	<5	8	.5	<.005	.3	.6	.1
7-21	1:30 pm	2.8	13.2	77	7.2	500	<5	13	.2	<.005	.2	.3	.2
7-22	3:25 pm	12.0	8.2	83	7.9	380	<5	35	<.1	<.005	.4	.3	.3
7-23	9:00 am	11.0	4.3	78	8.7	360	<5	35	.2	<.005	.2	.8	.1
7-23	2:45 pm	4.0	8.8	82	7.4	380	<5	37	.2	<.005	.3	.7	.2
Dry Weather Average		7.6	8.6	80	7.5	428	<5	23	.2**	<.005**	.3	.5	.2
7-28	3:35 pm	11.0	6.1	77	9.5	500	<5	29	.8	<.005	.1	.7	.4
7-29	10:45 am	4.5	6.6	71	7.2	365	<5	20	1.1	<.005	<.1	.9	.2
7-29	3:10 pm	5.0	8.5	75	7.6	400	<5	13	1.1	<.005	<.1	.7	.2
7-30	9:10 am	4.0	7.4	71	7.7	530	<5	13	1.2	<.005	.1	.4	.3
7-30	2:20 pm	104.0	7.1	73	-	500	<5	56	1.1	<.005	<.1	2.2	.6
7-31	10:35 am	13.0	4.7	72	7.5	380	<5	25	1.8	<.005	.3	.5	.4
7-31	1:30 pm	11.0	4.9	79	7.2	550	<5	23	1.9	<.005	.2	.4	.4
Wet Weather Average		8.0*	6.5	74	7.8	461	<5	26	1.3	<.005**	.1**	.8	.4
Overall Average		8.0*	7.5	77	7.6	446	<5	25	.7**	<.005**	.2**	.7	.3

* Average does not include heavy runoff
** Approximation

STATION 14 - Wilson Creek above the Southwest Sewage Treatment Plant

Date 1968	Time CDT	Q cfs	D.O mg/l	Temp. °F	pH	Cond. µmho/cm at 25°C	BOD mg/l	COD mg/l	NO3-N mg/l	NO2-N mg/l	NH3-N mg/l	Org.N mg/l	PO4-P mg/l
7-20	3:55 pm	2.7	13.0	88	8.6	345	<5	15	.1	<.005	.1	.4	.1
7-21	8:30 am	0.9	6.8	77	8.0	380	<5	9	<.1	<.005	.1	.6	.1
7-21	1:55 pm	2.0	13.4	88	8.3	380	<5	33	<.1	<.005	.4	.8	.3
7-22	2:35 pm	4.0	13.9	88	8.2	365	<5	31	<.1	<.005	.1	.9	.2
7-23	9:05 am	1.5	7.2	78	7.9	435	5	34	.1	<.005	.3	.5	.3
7-23	1:00 pm	3.5	19.6	89	8.8	370	7	57	<.1	<.005	.2	2.0	.1
Dry Weather Average		2.4	12.3	85	8.3	379	<5	30	<.1	<.005**	.2	.9	.2
7-28	2:45 pm	-	6.5	78	7.2	190	<5	27	.8	<.005	.1	.7	.3
7-29	9:40 am	2.4	7.8	75	8.4	460	<5	20	.5	<.005	<.1	.5	.2
7-29	2:30 pm	4.9	10.4	83	8.4	280	<5	22	.4	<.005	<.1	.6	.2
7-30	10:15 am	2.4	9.7	72	7.8	370	<5	18	.4	<.005	.2	.2	.3
7-30	1:35 pm	3.6	8.0	73	7.8	430	<5	17	.6	<.005	<.1	.5	.2
7-31	9:30 am	9.5	6.1	75	6.6	600	<5	32	1.6	<.005	.2	.6	.4
7-31	12:45 pm	9.5	7.0	80	-	320	6	33	1.6	<.005	.3	.7	.4
Wet Weather Average		5.4	7.9	77	7.7	379	<5	24	0.8	<.005**	<.14**	.5	.3
Overall Average		3.9	9.9	81	8.0	379	<5	27	0.4	<.005**	.2	.7	.2

** Approximation

STATION 15 - Southwest Sewage Treatment Plant
Influent (grab samples)

Date 1968	Time CDT	Q cfs	D.O. mg/1	Temp. °F	pH	Cond. µmho/cm at 25°C	BOD mg/1	COD mg/1	NO$_3$-N mg/1	NO$_2$-N mg/1	NH$_3$-N mg/1	Org.N mg/1	PO$_4$-P mg/1	Susp. Solids mg/1
7-20	5:00 pm	14.2	0.0	77	6.6	1080	369	607	.1	<.005	13.1	13.4	-	205
7-21	8:50 am	7.9	0.5	75	7.2	700	226	297	<.1	.025	7.4	7.9	1.3	115
7-21	2:10 pm	12.4	0.0	75	6.2	800	436	469	<.1	.023	[illegible]	-	19.0	165
7-22	3:35 pm	20.8	0.0	75	7.2	940	336	694	<.1	.013	11.2	23.6	18.5	345
7-23	9:30 am	12.7	0.7	76	7.2	680	371	402	<.1	.015	13.8	11.8	6.4	230
7-23	1:10 pm	19.8	0.0	80	7.3	940	329	595	<.1	.043	10.7	22.1	11.0	-
Dry Weather Average		14.6	0.2	76	6.9	856	346	511	<.1	.021**	11.2	15.8	11.2	212
7-28	2:40 pm	15.8	0.7	75	7.3	605	267	268	.1	<.005	14.0	10.4	10.0	-
7-29	10:15 am	17.5	-	77	7.6	900	223	348	<.1	<.005	1.2	27.6	5.5	-
7-29	3:10 pm	20.1	0.0	78	7.3	925	289	582	<.1	<.005	5.9	24.3	19.0	-
7-30	11:10 am	18.1	0.0	73	6.8	1020	296	503	<.1	<.005	22.1	9.2	8.4	104
7-30	2:00 pm	19.2	0.0	77	6.4	950	357	692	<.1	<.005	12.0	15.3	11.0	180
7-31	10:00 am	20.5	0.0	77	5.7	900	185	346	.9	<.005	7.5	8.3	6.8	188
7-31	1:00 pm	25.0	0.2	78	-	1000	364	417	.1	<.005	8.5	11.0	12.0	472
Wet Weather Average		19.5	0.2	76	6.9	900	283	451	0.2**	<.005**	10.2	15.2	10.4	236
Overall Average		17.2	0.2	76	6.9	880	312	479	0.14**	.01**	10.6	15.4	10.7	223

** Approximation

STATION 17 - Southwest Sewage Treatment Plant
Final Effluent (grab samples)

Date 1968	Time CDT	Q cfs	D.O. mg/1	Temp. °F	pH	Cond. µmho/cm at 25°C	BOD mg/1	COD mg/1	NO_3-N mg/1	NO_2-N mg/1	NH_3-N mg/1	Org.N mg/1	PO_4-P mg/1	Susp. Solids mg/1
7-20	5:20 pm	14.2	1.8	80	7.2	1020	6	42	<.05	<.005	19.6	1.8	6.4	70
7-21	9:10 am	7.9	2.3	79	7.6	1100	5	43	<.1	<.005	21.0	1.0	5.2	60
7-21	2:30 pm	12.4	6.2	80	7.0	1100	6	48	<.1	<.005	23.8	1.3	12.5	13
7-22	3:15 pm	20.8	5.4	79	7.6	1000	27	76	<.1	<.005	23.5	4.7	10.0	58
7-23	9:20 am	12.7	1.2	79	7.5	905	10	55	<.1	.010	17.5	3.5	4.0	58
7-23	1:25 pm	19.8	2.8	81	7.2	860	9	56	<.1	<.005	19.1	.9	10.0	30
Dry Weather Average		14.6	3.3	80	7.4	998	11	53	<.1	<.005**	20.8	2.2	8.0	48
7-28	3:05 pm	15.8	1.9	77	7.0	690	<5	43	<.1	<.005	13.1	.1	9.0	68
7-29	10:05 am	17.5	3.0	70	7.8	920	6	29	<.1	<.005	17.7	1.1	9.2	-
7-29	2:55 pm	20.1	0.7	79	7.2	860	14	50	<.1	<.005	16.7	2.7	7.8	-
7-30	10:45 am	18.1	6.0	73	7.2	1000	9	55	<.1	<.005	15.8	1.6	11.0	-
7-30	1:50 pm	19.2	6.0	77	7.1	1000	6	52	<.1	<.005	14.0	1.5	12.0	80
7-31	9:45 am	20.5	2.4	77	6.2	1000	<5	35	.1	<.005	11.6	<.1	6.5	54
7-31	1:15 pm	25.0	5.8	73	-	750	<5	35	.1	<.005	10.6	<.1	6.0	108
Wet Weather Average		19.5	3.7	75	7.1	889	6**	43	<.1	<.005**	14.2	1.0**	8.8	78
Overall Average		17.2	3.5	77	7.3	939	8	48	<.1	<.005**	17.2	1.6	8.4	60

** Approximation

STATION 20 - South Creek at Road FF

Date 1968	Time CDT	Q cfs	D.O. mg/1	Temp. °F	pH	Cond. µmho/cm at 25°C	BOD mg/1	COD mg/1	NO_3-N mg/1	NO_2-N mg/1	NH_3-N mg/1	Org.N mg/1	PO_4-P mg/1
7-20	3:30 pm	1.6	9.6	86	8.6	590	6	10	.1	<.005	.4	.5	.7
7-21	9:30 am	0.8	9.4	79	7.4	380	<5	12	.3	<.005	.2	.3	.5
7-21	3:00 pm	0.8	10.8	86	7.1	380	<5	11	.1	<.005	.4	.1	.6
7-22	2:20 pm	0.8	11.6	87	7.5	385	<5	10	.1	<.005	.2	.5	.5
7-23	8:50 am	2.8	7.8	78	7.9	375	<5	16	.3	<.005	.6	.4	.6
7-23	1:50 pm	0.8	10.8	88	8.2	480	8	24	.1	<.005	.1	2.0	.3
Dry Weather Average		1.3	10.0	84	7.8	432	5^{**}	14	.2	<.005**	.3	.6	.5
7-28	3:35 pm	5.6	8.4	78	7.6	320	<5	19	.2	<.005	.3	.3	.6
7-29	9:25 am	-	8.6	77	8.4	680	<5	11	.3	<.005	<.1	.5	.4
7-29	2:10 pm	2.8	10.5	82	8.1	490	<5	13	.3	<.005	<.1	.7	.3
7-30	10:00 am	0.8	9.8	71	7.6	510	6	8	.3	<.005	.3	<.1	.5
7-30	12:00 N	0.8	8.0	74	7.8	550	<5	11	.3	<.005	.1	.2	.5
7-31	9:15 am	1.9	7.0	77	6.8	900	<5	18	.3	<.005	.2	.7	.3
7-31	1:35 pm	0.8	8.2	82	-	540	<5	9	.3	<.005	-	-	.2
Wet Weather Average		2.1	8.6	77	7.7	570	<5	13	.3	<.005**	.2**	.4**	.4
Overall Average		1.7	9.2	80	7.8	506	5^{**}	13	.2	<.005**	.2**	.5**	.4

** Approximation

STATION 21 - Wilson Creek below sewage treatment
plant at flow gage

Date 1968	Time CDT	Q cfs	D.O mg/l	Temp. °F	pH	Cond. µmho/cm at 25°C	BOD mg/l	COD mg/l	NO_3-N mg/l	NO_2-N mg/l	NH_3-N mg/l	Org.N mg/l	PO_4-P mg/l
7-20	4:30 pm	17.5	4.8	81	7.4	925	8	43	.1	<.005	17.1	2.1	7.2
7-21	10:00 am	9.8	5.7	81	7.3	810	6	50	.1	<.005	17.6	.3	6.4
7-21	2:45 pm	14.7	5.6	82	6.4	1050	<5	46	.1	<.005	21.5	1.0	12.4
7-22	3:00 pm	21.5	6.9	79	7.5	930	26	64	.1	<.005	22.3	2.9	8.8
7-23	9:45 am	15.1	6.0	80	7.7	900	8	57	.1	<.005	19.4	2.8	3.9
7-23	1:35 pm	20.0	7.0	84	7.6	200	11	46	<.1	<.005	18.1	1.4	3.8
Dry Weather Average		16.4	6.0	81	7.3	803	10	51	.1**	<.005**	19.3	1.8	7.1
7-28	3:15 pm	25.0	6.0	78	7.2	500	<5	37	.4	<.005	6.3	<.1	5.2
7-29	9:55 am	17.5	6.7	77	7.8	850	<5	43	.2	<.005	14.6	.7	7.5
7-29	2:45 pm	21.5	6.6	80	7.3	775	11	49	.1	<.005	14.4	1.6	7.5
7-30	10:30 am	17.5	6.5	73	7.4	960	11	52	.2	<.005	14.8	.4	11.0
7-30	1:45 pm	19.0	5.8	76	7.3	850	8	42	.2	<.005	13.0	.5	10.0
7-31	9:40 am	24.0	6.2	79	6.4	825	<5	44	.8	<.005	4.8	<.1	3.6
7-31	1:25 pm	29.6	6.4	78	-	580	<5	31	.6	<.005	6.6	.5	4.1
Wet Weather Average		22.0	6.3	77	7.2	763	6**	43	.4	<.005**	10.7	.5**	7.0
Overall Average		19.4	6.2	79	7.2	781	8**	47	.3	<.005**	14.6	1.1	7.0

** Approximation

STATION 23 - Rader Sink

Date 1968	Time CDT	Q cfs	D.O. mg/l	Temp. °F	pH	Cond. µmho/cm at 25°C	BOD mg/l	COD mg/l	NO_3-N mg/l	NO_2-N mg/l	NH_3-N mg/l	Org.N mg/l	PO_4-P mg/l
7-20	2:20 pm	6.0	4.4	85	7.6	805	16	63	.4	.01	16.4	2.1	7.0
7-21	10:25 am	2.2	1.6	78	7.3	1100	9	54	.1	.065	-	-	6.2
7-21	3:15 pm	-	4.2	84	6.6	1000	<5	45	.2	.050	19.8	0.8	12.4
7-22	1:30 pm	12.0	4.9	81	7.6	830	9	46	.1	.070	20.8	1.6	8.0
7-23	8:30 am	2.2	1.4	77	7.5	790	23	51	<.1	<.005	11.2	4.6	8.3
7-23	2:05 pm	2.2	4.1	85	7.8	900	22	49	.1	.065	18.1	2.3	9.3
Dry Weather Average		4.9	3.4	82	7.4	904	14**	51	.2	.03	17.3	2.3	8.5
7-28	3:50 pm	6.0	5.0	78	7.6	500	11	43	.5	<.005	5.9	1.5	5.0
7-29	9:15 am	2.2	2.9	73	7.7	750	7	40	.5	<.005	8.8	4.2	7.2
7-29	1:25 pm	6.0	5.6	79	7.3	690	7	40	.6	<.005	12.7	1.4	6.5
7-30	8:15 am	2.2	1.9	72	7.3	1000	17	-	-	-	-	-	-
7-30	pm	No run											
7-31	8:40 am	2.1	3.5	77	6.6	600	5	36	.7	<.005	4.2	<.1	3.1
7-31	2:10 pm	8.0	4.4	80	-	600	<5	37	.7	<.005	6.6	<.1	4.0
Wet Weather Average		4.4	3.9	77	7.3	690	9**	39	.6	<.005**	7.6	1.5	5.2
Overall Average		4.6	3.6	80	7.4	797	11**	45	.4	.015	12.4	1.9	7.0

** Approximation

STATION 24 - Wilson Creek at Rader Bridge

Date 1968	Time CDT	Q cfs	D.O mg/1	Temp. °F	pH	Cond. µmho/cm at 25°C	BOD mg/1	COD mg/1	NO_3-N mg/1	NO_2-N mg/1	NH_3-N mg/1	Org.N mg/1	PO_4-P mg/1
7-20	1:45 pm	9.8	4.2	85	7.8	755	16	63	.2	<.005	15.5	4.5	6.1
7-21	10:40 am	4.4	2.9	76	7.4	1120	9	49	.1	<.005	18.6	.5	14.2
7-21	3:30 pm	9.9	4.8	84	6.8	1000	10	53	<.1	.043	18.9	1.4	12.4
7-22	1:50 pm	14.0	4.8	81	7.6	825	8	46	.1	.063	22.3	.1	8.5
7-23	8:00 am	6.0	1.3	77	7.5	775	21	75	.1	<.005	12.6	3.7	4.8
7-23	2:15 pm	9.8	5.3	85	7.6	260	12	51	.2	.052	17.6	3.6	3.8
Dry Weather Average		9.0	3.8	81	7.5	789	13	56	.1**	0.03	17.6	2.3	8.3
7-28	4:00 pm	21.0	-	-	-	-	-	-	-	-	-	-	-
7-29	9:05 am	6.0	3.4	75	8.2	800	7	40	.5	<.005	9.1	3.3	7.0
7-29	1:40 pm	14.0	-	-	-	-	-	-	-	-	-	-	-
7-30	9:25 am	6.0	2.0	72	7.3	1000	16	50	.2	<.005	14.9	1.2	12.0
7-30	1:20 pm	14.0	3.0	76	7.2	950	<5	<4	.5	<.005	13.6	.8	10.0
7-31	8:55 am	14.0	3.7	77	6.6	750	8	30	.7	<.005	4.3	<.1	2.6
7-31	2:00 pm	20.0	5.4	80	-	600	<5	32	.8	<.005	7.3	<.1	3.6
Wet Weather Average		13.6	3.5	76	7.3	820	8**	31**	.5	<.005**	9.9	1.1**	7.0
Overall Average		11.5	3.7	79	7.4	803	11	45	.3	0.015	14.1	1.8	7.7

** Approximation

STATION 25 - Rader Spring

Date 1968	Time CDT	Q cfs	D.O mg/1	Temp. °F	pH	Cond. µmho/cm at 25°C	BOD mg/1	COD mg/1	NO_3-N mg/1	NO_2-N mg/1	NH_3-N mg/1	Org.N mg/1	PO_4-P mg/1
7-20	2:50 pm	15.5	1.7	67	6.8	585	6	17	2.5	<.005	4.2	.1	3.2
7-21	10:55 am	9.4	1.2	68	6.9	620	<5	15	2.6	.008	4.3	<.1	2.8
7-21	3:45 pm	13.0	1.2	67	5.0	700	<5	10	2.6	<.005	5.5	0.0	7.2
7-22	1:30 pm	17.5	3.2	65	6.8	600	<5	13	2.6	<.005	3.3	<.1	4.0
7-23	8:20 am	15.0	1.4	67	7.3	535	<5	24	2.2	<.005	2.6	.6	2.6
7-23	2:20 pm	20.0	1.5	68	7.3	530	<5	18	1.9	.013	2.0	1.3	1.4
Dry Weather Average		15.1	1.7	67	6.7	595	<5	16	2.4	0.006	3.7	.4	3.5
7-28	4:05 pm	23.5	2.0	68	7.2	450	<5	14	2.6	<.005	1.8	.6	2.4
7-29	8:45 am	15.0	1.3	72	9.0	680	<5	19	2.4	<.005	1.9	.6	2.0
7-29	1:50 pm	19.5	1.0	68	6.3	490	<5	16	2.5	<.005	1.9	1.0	1.8
7-30	9:40 am	13.0	1.1	64	6.7	620	10	18	2.4	<.005	3.8	.4	3.5
7-30	1:10 pm	17.5	1.8	67	6.5	675	5	20	2.4	<.005	4.3	.6	3.3
7-31	9:05 am	22.5	3.1	70	6.0	640	6	19	4.2	<.005	1.6	<.1	.1
7-	1:45 pm	24.0	2.0	70	-	420	<5	17	3.4	<.005	<.1	-	1.2
Wet Weather Average		19.3	1.8	68	7.0	568	6**	18	2.8	<.005**	2.2**	.6	2.0
Overall Average		17.4	1.8	68	6.8	580	5**	17	2.6	0.003	2.9	.5	2.7

** Approximation

STATION 27 - Wilson Creek at north edge of National Park

Date 1968	Time CDT	Q cfs	D.O mg/1	Temp. °F	pH	Cond. μmho/cm at 25°C	BOD mg/1	COD mg/1	NO_3-N mg/1	NO_2-N mg/1	NH_3-N mg/1	Org.N mg/1	PO_4-P mg/1
7-20	1:40 pm	32.5	5.6	73	6.8	800	9	33	1.6	.065	8.6	.5	5.2
7-21	8:35 am	27.2	2.3	71	7.5	900	9	30	1.2	.015	9.8	1.9	6.0
7-21	1:40 pm	26.0	5.8	77	7.8	950	<5	33	1.7	.113	8.9	.6	5.9
7-22	1:45 pm	40.0	6.2	76	6.4	700	<5	24	1.9	.052	6.3	1.0	2.9
7-23	8:40 am	36.0	2.5	70	7.0	675	13	35	.6	<.005	8.8	1.5	5.8
7-23	1:00 pm	36.0	5.2	75	7.3	610	13	34	1.2	.036	5.2	1.6	2.2
Dry Weather Average		33.0	4.6	74	7.1	773	9**	32	1.4	0.05	7.9	1.2	4.7
7-28	2:45 pm	56.5	3.8	74	8.2	460	<5	34	1.6	<.005	2.4	.3	3.3
7-29	9:10 am	32.5	2.6	68	7.4	600	7	17	1.8	<.005	2.4	3.6	3.5
7-29	1:10 pm	36.0	4.9	75	7.6	750	<5	29	2.0	<.005	5.4	.3	3.2
7-30	10:40 am	29.0	2.8	70	7.8	625	10	34	1.6	<.005	9.5	.7	6.5
7-30	12:30 pm	29.7	2.4	70	6.8	750	10	-	-	-	-	-	-
7-31	8:45 am	65.5	2.0	70	7.2	580	10	25	1.8	<.005	2.3	.3	1.6
7-31	12:00 N	61.0	2.5	72	7.1	470	7	24	1.9	<.005	1.9	<.1	1.6
Wet Weather Average		44.3	3.0	71	7.4	605	7**	27	1.8	<.005**	4.0	.9	3.3
Overall Average		39.0	3.7	72	7.3	683	8**	30	1.6	0.025	6.0	1.0	4.0

** Approximation

STATION 29 - Terrell Creek at State Road ZZ

Date 1968	Time CDT	Q cfs	D.O mg/l	Temp. °F	pH	Cond. µmho/cm at 25°C	BOD mg/l	COD mg/l	NO_3-N mg/l	NO_2-N mg/l	NH_3-N mg/l	Org.N mg/l	PO_4-P mg/l
7-20	2:15 pm	6.0	9.0	70	6.5	400	<5	<4	3.8	<.005	<.1	.1	.1
7-21	9:25 am	5.5	8.3	67	7.6	365	<5	<4	3.9	<.005	.3	0.0	.1
7-21	2:00 pm	6.0	8.5	69	8.2	390	<5	8	3.7	<.005	.2	.3	.1
7-22	2:00 pm	6.6	9.0	70	6.2	450	<5	<4	4.0	<.005	.1	.1	.1
7-23	9:20 am	6.0	8.5	64	7.1	410	<5	<4	3.8	<.005	<.1	<.1	.2
7-23	1:20 pm	5.5	8.6	69	7.3	385	<5	<4	3.9	<.005	.1	<.1	.2
Dry Weather Average		5.9	8.7	68	7.2	400	<5	4**	3.9	<.005	.1**	.1**	.1
7-28	3:08 pm	8.6	8.0	64	6.0	400	<5	<4	3.9	<.005	.4	<.1	.2
7-29	9:50 am	6.8	8.0	66	7.7	420	<5	5	3.8	<.005	.1	<.1	<.1
7-29	1:15 pm	6.6	8.4	72	7.8	600	<5	5	3.7	<.005	.1	<.1	<.1
7-30	10:20 am	5.5	8.3	66	7.1	340	<5	<4	3.8	<.005	.1	<.1	<.1
7-30	12:10 pm	6.0	6.3	63	7.3	430	<5	<4	3.7	<.005	<.1	<.1	<.1
7-31	9:20 am	5.6	8.4	66	-	460	<5	7	2.7	<.005	<.1	.4	1.0
7-31	12:15 pm	5.5	9.3	66	7.3	420	<5	<4	3.9	<.1	.3	-	.2
Wet Weather Average		6.4	8.1	66	7.2	439	<5	4**	3.6	<.005**	.2**	.1**	.2
Overall Average		6.2	8.4	67	7.2	421	<5	4**	3.7	<.005**	.2**	.1**	.2

** Approximation

STATION 30 - Wilson Creek at Manley Ford

Date 1968	Time CDT	Q cfs	D.O mg/l	Temp. °F	pH	Cond. µmho/cm at 25°C	BOD mg/l	COD mg/l	NO$_3$-N mg/l	NO$_2$-N mg/l	NH$_3$-N mg/l	Org.N mg/l	PO$_4$-P mg/l
7-20	2:45 pm	8.0	6.0	73	6.9	700	6	25	1.7	.080	8.4	.5	4.5
7-21	9:50 am	8.0	3.0	72	7.5	645	<5	21	1.8	.030	5.3	1.7	4.1
7-21	2:20 pm	6.0	5.2	77	8.0	680	6	23	1.9	.125	6.5	.7	4.4
7-22	2:15 pm	11.0	5.6	77	6.6	700	<5	19	2.1	.033	6.9	.7	4.0
7-23	9:35 am	14.0	2.3	70	7.0	750	13	29	1.1	.020	10.1	.9	2.5
7-23	1:35 pm	11.0	4.6	76	6.4	760	17	37	1.2	.035	11.4	1.4	2.9
Dry Weather Average		9.6	4.5	74	7.1	706	8^{**}	26	1.6	.054	8.1	1.0	3.7
7-28	1:22 pm	40.0	3.4	75	6.2	360	7	27	1.7	<.005	1.6	.8	4.0
7-29	10:00 am	18.0	4.0	68	7.4	540	<5	22	2.2	<.005	2.7	.4	2.4
7-29	1:25 pm	16.0	4.6	73	7.4	680	<5	13	2.4	<.005	2.8	.3	2.5
7-30	10:00 am	16.0	3.0	70	7.3	540	7	25	2.1	<.005	6.3	.8	4.1
7-30	12:30 pm	13.5	3.5	68	7.2	660	7	22	2.0	<.005	6.3	.8	3.6
7-31	9:35 am	25.0	2.6	70	-	540	<5	29	1.7	<.005	1.6	.4	1.9
7-31	12:30 pm	35.0	2.8	72	7.2	520	9	24	1.6	<.005	2.6	1.3	1.9
Wet Weather Average		23.4	3.4	71	7.1	549	6^{**}	23	2.0	$<.005^{**}$	3.4	.7	2.9
Overall Average		17.0	3.9	72	7.1	621	7^{**}	24	1.8	$.03^{**}$	5.6	.8	3.3

** Approximation

STATION 33 - James River below Lake
Springfield Dam

Date 1968	Time CDT	Q cfs	D.O mg/1	Temp. °F	pH	Cond. µmho/cm at 25°C	BOD mg/1	COD mg/1	NO3-N mg/1	NO2-N mg/1	NH3-N mg/1	Org.N mg/1	PO4-P mg/1
7-20	1:40 pm	25.5	7.4	92	7.1	320	<5	22	.3	<.005	.1	1.0	.2
7-21	9:20 am	25.5	8.2	84	6.5	315	<5	11	.3	<.005	.1	1.0	.1
7-21	2:25 pm	28.0	13.8	91	8.1	290	<5	15	.2	<.005	.3	.7	.1
7-22	2:20 pm	25.5	7.6	91	8.4	290	<5	16	.3	<.005	.1	.8	.1
7-23	10:45 am	25.5	6.8	86	7.9	320	<5	8	.3	<.005	.1	.5	.0
7-23	1:35 pm	25.5	9.0	90	7.2	300	<5	10	.3	<.005	.1	.5	.2
Dry Weather Average		25.9	8.8	89	7.5	306	<5	14	.3	<.005**	.1	.8	.1
7-28	5:00 pm	60.0	6.8	86	8.8	550	<5	19	.2	<.005	.1	.5	.1
7-29	9:30 am	51.5	7.4	82	7.4	300	<5	11	.3	<.005	.1	.5	.2
7-29	2:30 pm	47.0	7.2	91	6.7	340	<5	16	.2	<.005	.1	.9	.1
7-30	8:35 am	65.8	6.7	88	8.0	280	<5	10	.3	<.005	.3	.5	.1
7-30	12:15 pm	67.5	6.5	88	7.8	290	<5	16	.3	<.005	.2	.6	.1
7-31	10:35 am	109.0	6.6	86	7.2	310	6	19	.4	<.005	<.1	.8	.2
7-31	12:00 N	105.0	6.5	88	7.0	300	6	12	.5	<.005	<.1	1.1	.1
Wet Weather Average		72.3	6.8	87	7.6	339	5**	15	.3	<.005**	.1**	.7	.1
Overall Average		51	7.7	88	7.6	324	<5	15	.3	<.005**	.1**	.7	.1

** Approximation

STATION 35 - James River at Racetrack Road

Date 1968	Time CDT	Q cfs	D.O. mg/1	Temp. °F	pH	Cond. umho/cm at 25°C	BOD mg/1	COD mg/1	NO_3-N mg/1	NO_2-N mg/1	NH_3-N mg/1	Org.N mg/1	PO_4-P mg/1
7-20	2:30 pm	28	7.0	81	7.2	360	<5	7	1.2	<.005	.1	.4	.1
7-21	9:55 am	29	6.4	75	6.5	360	<5	4	1.3	<.005	.1	.2	.1
7-21	3:30 pm	29	6.9	81	7.2	330	<5	11	1.1	<.005	.5	.1	.1
7-22	2:40 pm	27	7.4	84	8.8	340	<5	12	.8	<.005	.1	.3	.1
7-23	10:15 am	26	6.2	78	7.4	380	<5	7	1.3	<.005	.1	.4	.1
7-23	2:10 pm	26	7.6	77	7.0	350	<5	6	1.0	<.005	.2	.2	.2
Dry Weather Average		28	6.9	79	7.4	353	<5	8**	1.1	<.005**	.2	.3	.1
7-28	5:10 pm	60	6.1	79	7.7	310	<5	14	.8	<.005	.1	.4	.1
7-29	10:00 am	53	6.6	72	7.3	340	<5	11	.8	<.005	<.1	.5	.2
7-29	3:05 pm	55	7.6	80	-	350	<5	6	.6	<.005	<.1	.6	.1
7-30	9:40 am	70	6.3	79	6.8	310	<5	11	.8	<.005	.3	.2	.1
7-30	12:50 pm	72	6.1	-	6.7	315	<5	11	.8	<.005	<.1	.6	.1
7-31	10:00 am	110	5.9	79	7.2	330	<5	11	.7	<.005	<.1	.7	.1
7-31	12:25 pm	110	6.1	84	7.4	290	<5	12	.6	<.005	<.1	.6	.1
Wet Weather Average		76	6.4	79	7.2	321	<5	11	.7	<.005**	.1**	.5	.1
Overall Average		54	6.6	79	7.3	336	<5	9	.9	<.005**	.1**	.4	.1

** Approximation

STATION 36 - Indian Spring

Date 1968	Time CDT	Q cfs	D.O mg/1	Temp. °F	pH	Cond. µmho/cm at 25°C	BOD mg/1	COD mg/1	NO_3-N mg/1	NO_2-N mg/1	NH_3-N mg/1	Org.N mg/1	PO_4-P mg/1
7-20	3:20 pm	2.0	9.6	58	8.4	440	<5	<4	3.8	<.005	<.1	.2	.2
7-21	10:15 am	1.0	9.4	63	6.6	370	<5	<4	4.0	<.005	.1	.2	.1
7-21	3:00 pm	1.5	9.4	57	6.4	420	<5	10	3.6	<.005	.3	<.1	.1
7-22	3:40 pm	1.0	9.4	58	8.7	400	<5	<4	3.5	<.005	.2	<.1	.1
7-23	9:45 am	1.0	9.0	56	7.2	440	<5	<4	3.9	<.005	<.1	<.1	.1
7-23	2:30 pm	0.8	9.3	55	7.1	430	<5	<4	3.7	<.005	.1	<.1	.1
Dry Weather Average		1.2	9.4	58	7.4	417	<5	4**	3.8	<.005**	.2**	.1**	.1
7-28	4:25 pm	0.5	9.2	56	7.2	390	<5	5	3.7	<.005	<.1	.1	.0
7-29	10:25 am	0.8	9.8	56	6.9	420	<5	<4	3.8	<.005	<.1	.1	.3
7-29	4:10 pm	0.5	9.2	56	-	460	<5	<4	3.7	<.005	<.1	<.1	.1
7-30	9:10 am	0.8	8.3	59	2.7	400		<4	4.0	<.005	<.1	<.1	.1
7-30	1:40 pm	0.6	9.6	-	2.2	330		5	3.9	<.005	<.1	<.1	.1
7-31	9:35 am	0.8	9.5	57	7.1	440	<5	<4	4.0	<.005	<.1	.2	.0
7-31	1:40 pm	0.5	9.8	58	6.0	420	<5	<4	4.0	<.005	<.1	.3	.0
Wet Weather Average		0.6	9.3	57	5.4	409	<5	4**	3.9	<.005**	<.1	.2**	.1
Overall Average		0.9	9.3	58	6.4	413	<5	4**	3.9	<.005**	.1**	.1**	.1

** Approximation

STATION 37 - Blue Spring

Date 1968	Time CDT	Q cfs	D.O. mg/l	Temp. °F	pH	Cond. μmho/cm at 25°C	BOD mg/l	COD mg/l	NO_3-N mg/l	NO_2-N mg/l	NH_3-N mg/l	Org.N mg/l	PO_4-P mg/l
7-20	4:00 pm	8.	8.2	58	7.0	440	<5	<4	5.3	<.005	<.1	.3	.1
7-21	10:50 am	7.	8.4	58	6.6	400	<5	<4	5.7	<.005	.1	<.1	.1
7-21	3:50 pm	10.	8.0	59	6.8	400	<5	6	5.2	<.005	.3	<.1	.1
7-22	2:55 pm	6.0	8.4	59	8.4	415	<5	<4	5.4	<.005	.1	.1	.1
7-23	9:15 am	6.0	8.6	59	7.0	440	<5	<4	5.6	<.005	<.1	<.1	.1
7-23	3:35 pm	7.0	8.8	57	6.8	420	<5	<4	5.8	<.005	<.1	<.1	.2
Dry Weather Average		7.3	8.4	58	7.1	419	<5	4**	5.5	<.005**	.1**	.1**	.1
7-28	5:00 pm	8.0	8.4	58	7.4	380	<5	5	5.0	<.005	<.1	.3	.1
7-29	10:50 am	7.0	9.1	57	7.0	420	<5	<4	5.1	<.005	<.1	<.1	.1
7-29	3:25 pm	2.0	8.8	59	-	455	<5	<4	5.1	<.005	<.1	<.1	.1
7-30	9:55 am	4.5	8.4	62	4.2	380		5	5.1	<.005	<.1	<.1	.1
7-30	1:05 pm	10.0	8.6	-	6.7	340		<4	5.2	<.005	<.1	<.1	.1
7-31	9:10 am	7.0	9.0	57	6.8	430	<5	<4	5.2	<.005	<.1	.3	.1
7-31	12:45 pm	10.0	8.7	57	6.9	400	6	<4	5.2	<.005	.1	.4	.1
Wet Weather Average		6.9	8.7	58	6.5	401	<5	4**	5.1	<.005**	<.1	.2**	.1
Overall Average		7.1	8.6	58	6.8	409	<5	4**	5.3	<.005**	.1**	.1**	.1

** Approximation

STATION 39 - James River at
Nelson Mill Bridge

Date 1968	Time CDT	Q cfs	D.O mg/l	Temp. °F	pH	Cond. µmho/cm at 25°C	BOD mg/l	COD mg/l	NO_3-N mg/l	NO_2-N mg/l	NH_3-N mg/l	Org.N mg/l	PO_4-P mg/l
7-20	4:30 pm	33.0	8.6	80	7.8	360	<5	<4	2.0	<.005	.1	1.1	.1
7-21	11:15 am	35.0	7.9	74	6.4	365	<5	15	2.0	<.005	.2	.3	<.1
7-21	4:10 pm	30.0	6.9	78	7.7	340	<5	14	2.0	<.005	.4	.1	.1
7-22	3:15 pm	30.0	7.4	80	8.6	350	<5	7	1.9	<.005	.1	.2	.1
7-23	9:00 am	28.0	6.6	76	7.8	380	<5	8	1.9	<.005	.1	.2	.1
7-23	3:10 pm	28.0	8.6	77	7.4	370	6	10	1.8	<.005	.1	.4	.1
Dry Weather Average		31.0	7.7	78	7.6	361	<5	10**	1.9	<.005**	.2	.4	.1
7-28	4:40 pm	65.0	6.8	75	7.5	330	<5	13	1.8	<.005	<.1	.7	.1
7-29	11:10 am	60.0	6.7	70	6.8	350	<5	<4	1.5	<.005	<.1	.3	.1
7-29	3:40 pm	60.0	6.0	76	7.3	360	<5	10	1.5	<.005	<.1	.5	.1
7-30	10:10 am	80.0	6.8	77	6.2	300	<5	7	1.4	<.005	<.1	.3	.1
7-30	1:25 pm	80.0	6.7	-	5.3	320	<5	11	1.5	<.005	<.1	.5	.1
7-31	8:45 am	120.0	6.4	72	7.3	360	<5	11	1.2	<.005	.1	.4	.1
7-31	1:10 pm	120.0	6.7	76	6.8	335	<5	8	1.1	<.005	.3	.3	.1
Wet Weather Average		84.0	6.6	74	6.7	36	<5	9**	1.4	<.005**	.1**	.4	.1
Overall Average		59.0	7.1	76	7.1	348	<5	9**	1.6	<.005**	.1**	.4	.1

** Approximation

STATION 40 - James River at
Highway 14

Date 1968	Time CDT	Q cfs	D.O mg/l	Temp. °F	pH	Cond. µmho/cm at 25°C	BOD mg/l	COD mg/l	NO_3-N mg/l	NO_2-N mg/l	NH_3-N mg/l	Org.N mg/l	PO_4-P mg/l
7-20	3:20 pm	66	6.7	81	.2	485	17	21	2.5	.110	.9	.8	1.9
7-21	11:40 am	63	6.2	83	7.5	455	<5	18	2.8	.125	1.0	1.1	1.9
7-21	2:50 pm	60	15.2	84	8.4	470	<5	28	2.7	.158	1.5	1.4	1.8
7-22	2:45 pm	65	6.0	82	6.5	600	<5	19	2.8	.099	1.8	1.0	2.6
7-23	10:10 am	64	3.4	73	6.8	480	8	16	2.5	.108	1.0	.5	2.0
7-23	1:55 pm	62	6.6	82	7.4	485	8	19	2.7	.105	.5	.7	.9
Dry Weather Average		63	7.4	81	7.3	496	8^{**}	20	2.7	.118	1.1	.9	1.8
7-28	3:40 pm	140	4.4	76	5.8	520	<5	29	1.7	<.005	2.4	.4	2.2
7-29	10:20 am	104	4.6	71	7.2	410	<5	17	2.4	<.005	<.1	.9	1.0
7-29	1:50 pm	103	7.6	81	7.4	540	<5	12	2.4	<.005	.6	.4	1.0
7-30	9:35 am	118	4.6	73	7.3	375	5	14	2.7	<.005	1.1	.7	1.1
7-30	1:10 pm	116	4.5	70	7.3	440	<5	13	2.6	<.005	1.0	.3	1.2
7-31	10:00 am	176	4.0	76	-	380	<5	20	1.8	<.005	.9	.5	.9
7-31	12:55 pm	182	4.9	72	7.5	400	6	19	1.8	<.005	.7	.8	1.0
Wet Weather Average		134	4.9	74	7.1	438	5^{**}	18	2.2	$<.005^{**}$	1.0	.6	1.2
Overall Average		101	6.1	77	7.2	465	6^{**}	19	2.4	$.06^{**}$	1.0	.7	1.5

** Approximation

STATION 41 - James River at
Bernet Farm

Date 1968	Time CDT	Q cfs	D.O. mg/1	Temp. °F	pH	Cond. µmho/cm at 25°C	BOD mg/1	COD mg/1	NO_3-N mg/1	NO_2-N mg/1	NH_3-N mg/1	Org.N mg/1	PO_4-P mg/1
7-20	4:00 pm	91	7.6	81	7.2	460	<5	18	3.5	.140	.5	.8	1.9
7-21	11:05 am	83	3.9	76	7.4	505	<5	14	3.9	.133	.3	.8	1.8
7-21	3:35 pm	83	6.0	81	8.5	450	9	17	3.5	.198	.6	1.1	1.7
7-22	3:15 pm	88	7.0	82	6.2	500	<5	20	3.7	.123	.6	.7	1.8
7-23	10:45 am	86	3.1	74	6.7	540	<5	14	2.3	.155	.7	.2	2.5
7-23	2:25 pm	86	5.8	81	7.3	490	11	23	3.5	.100	.6	1.3	.9
Dry Weather Average		86	5.6	79	7.2	491	5**	18	3.4	142	.6	.8	1.7
7-28	4:15 pm	176	4.0	76	6.5	440	7	21	2.8	<.005	1.3	1.0	2.0
7-29	10:50 am	130	3.4	72	6.9	390	<5	19	2.6	<.005	.6	.4	1.4
7-29	2:10 pm	130	6.5	79	7.6	460	<5	24	2.6	<.005	.5	.5	1.2
7-30	9:00 am	139	4.2	72	7.5	350	<5	17	2.6	<.005	<.1	.9	1.0
7-30	1:40 pm	139	5.5	72	7.5	400	<5	11	2.9	<.005	.3	.8	1.0
7-31	10:30 am	208	3.0	74	7.2	380	5	26	2.1	<.005	<.1	.9	1.0
7-31	1:30 pm	208	3.6	73	7.3	320	7	24	2.2	<.005	.7	1.0	1.0
Wet Weather Average		161	4.3	74	7.2	399	5**	20	2.6	<.005**	0.5	.8	1.2
Overall Average		126	4.9	76	7.2	441	5**	19	3.0	.07**	.5	.8	1.5

** Approximation

SELECTED MONITOR STRIP CHART RECORDS

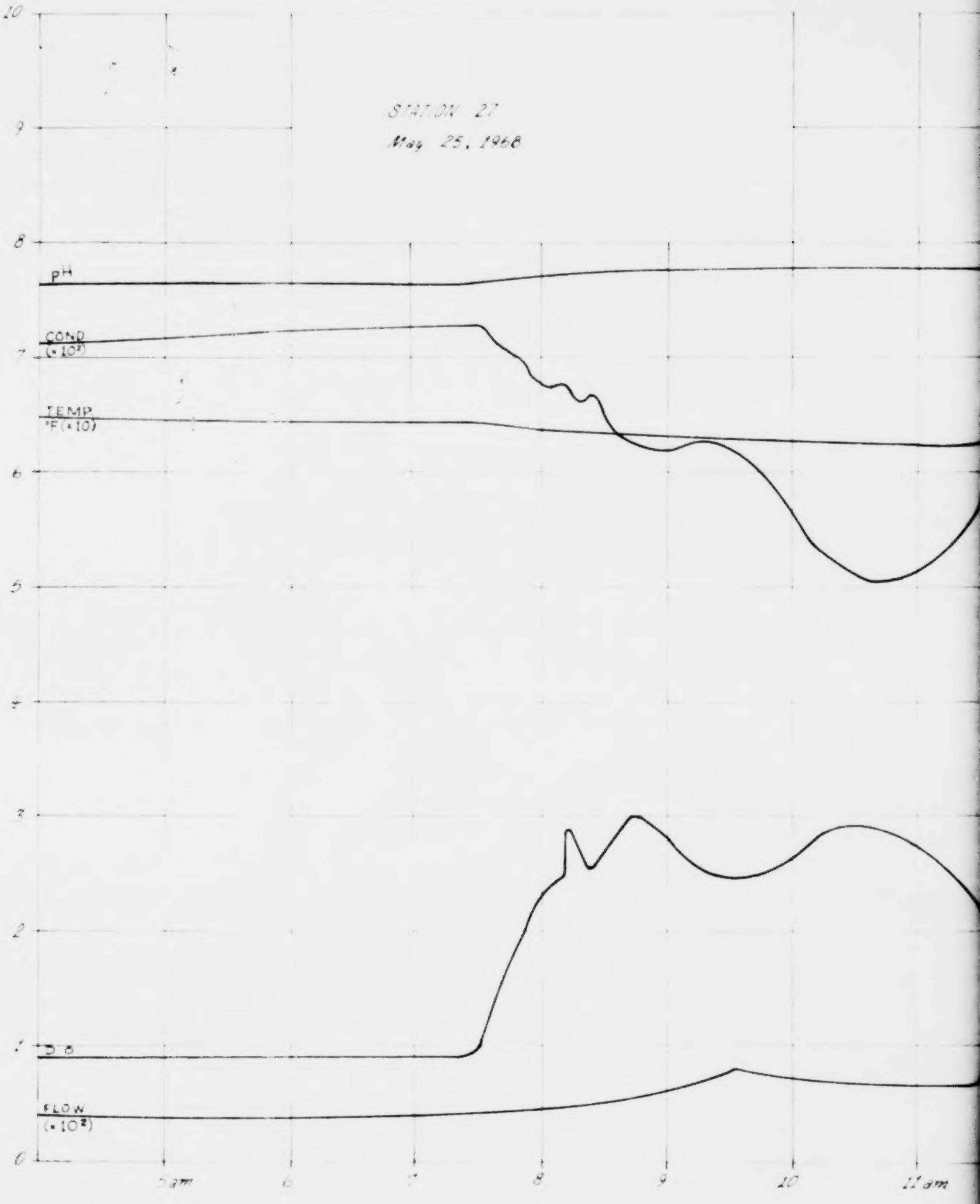
Station 27

Station 41

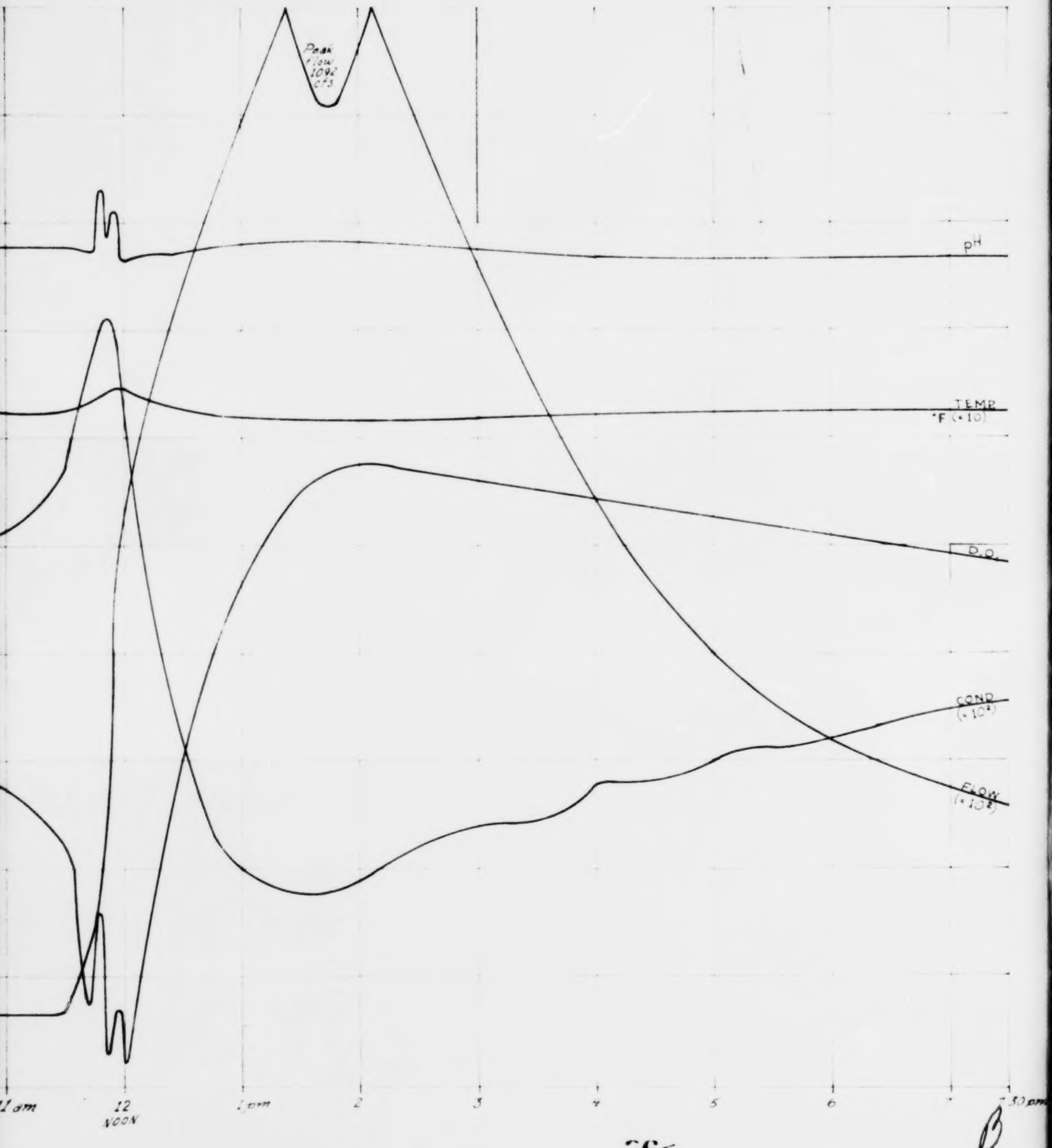
Station 14

Station 25

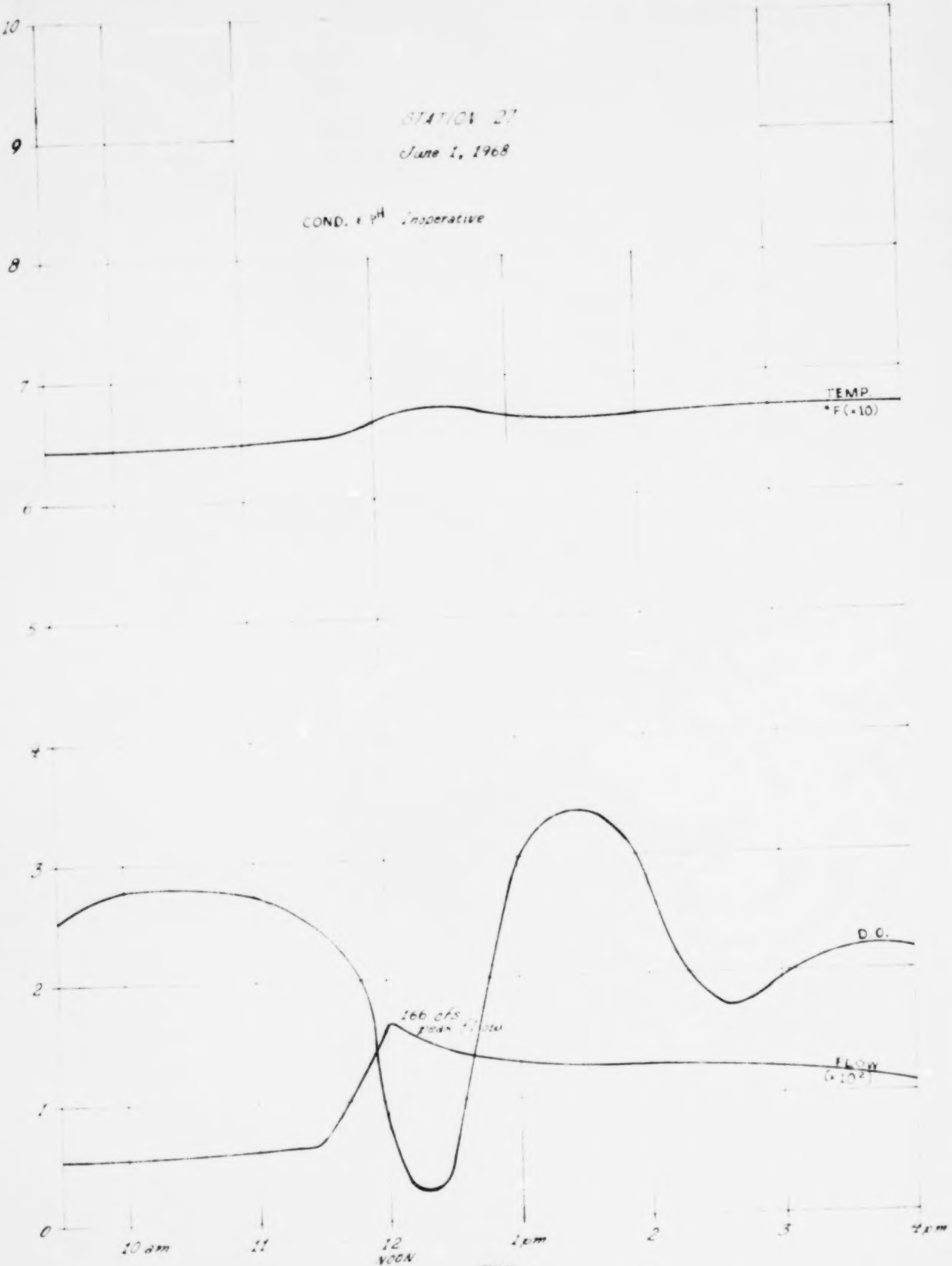
All flow readings are cubic feet per second
Dissolved Oxygen (DO) in milligrams per liter
Temperature in degrees Fahrenheit
Conductivity in micromhos per centimeter at 25°

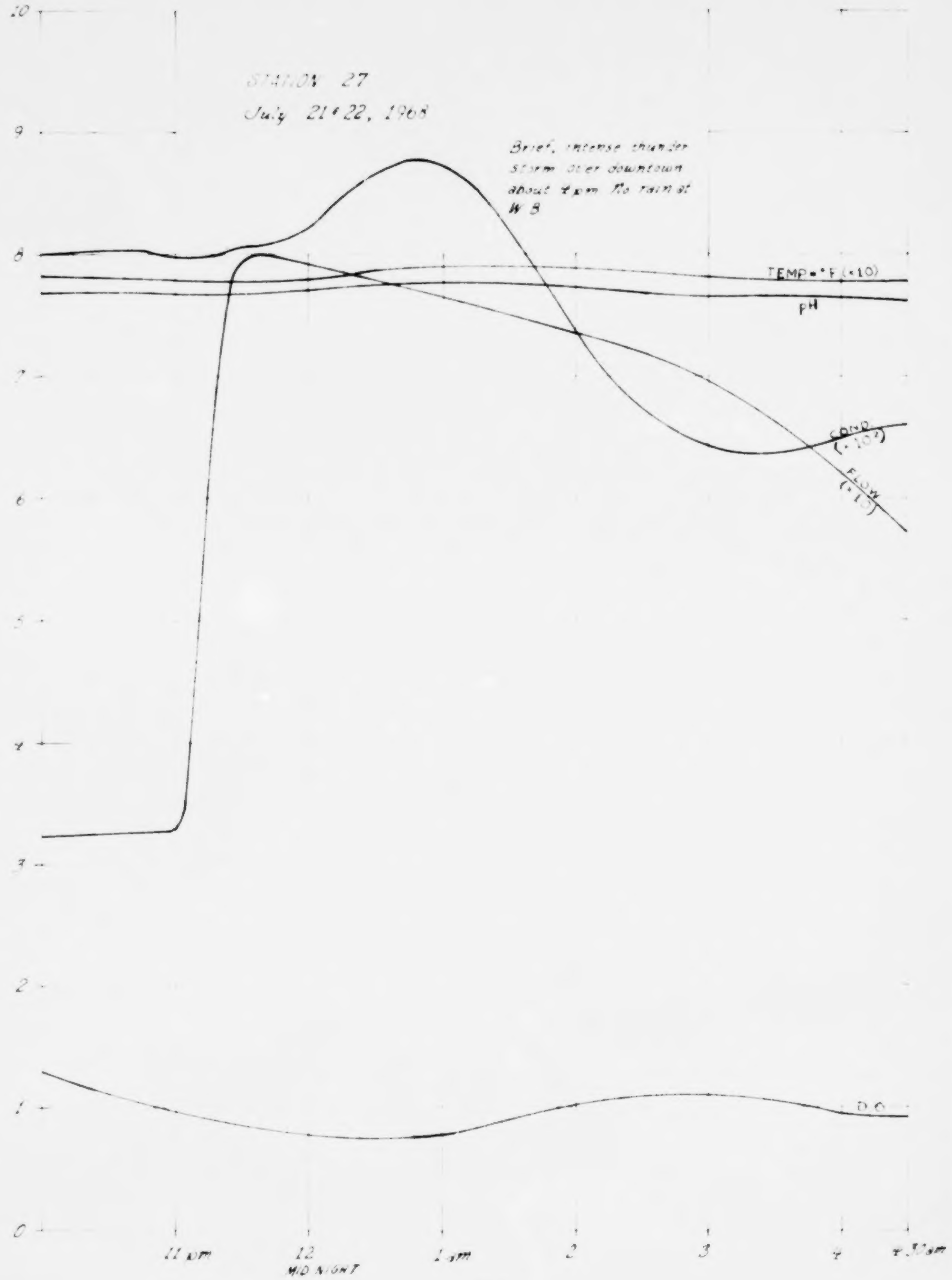


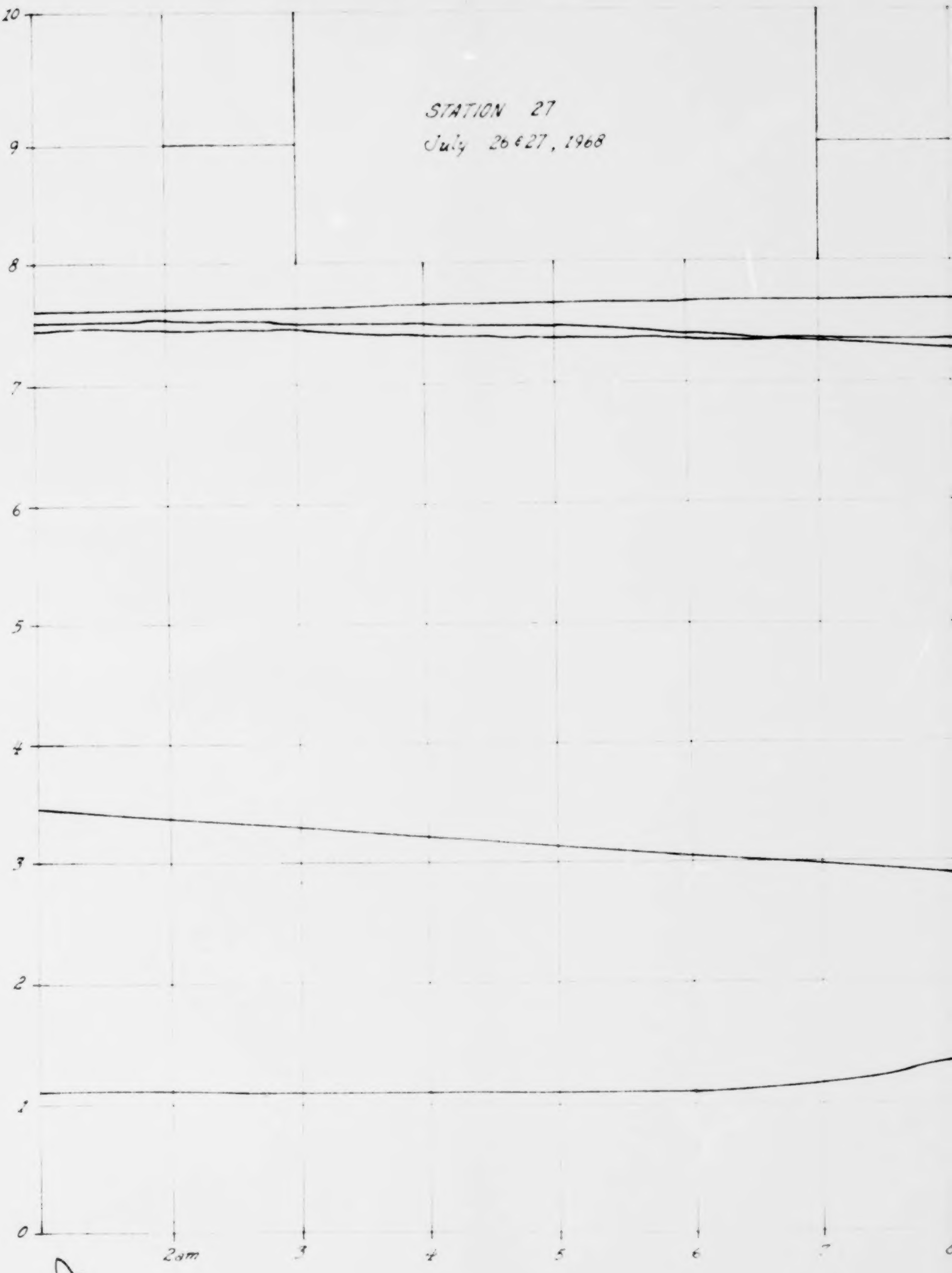
STATION 27
May 25, 1968


Peak flow 1092 cfs
pH
TEMP °F (×10)
D.O.
COND (×10²)
FLOW (×10²)
11 am
12 NOON
1 pm
2
3
4
5
6
7
7 30 pm

B

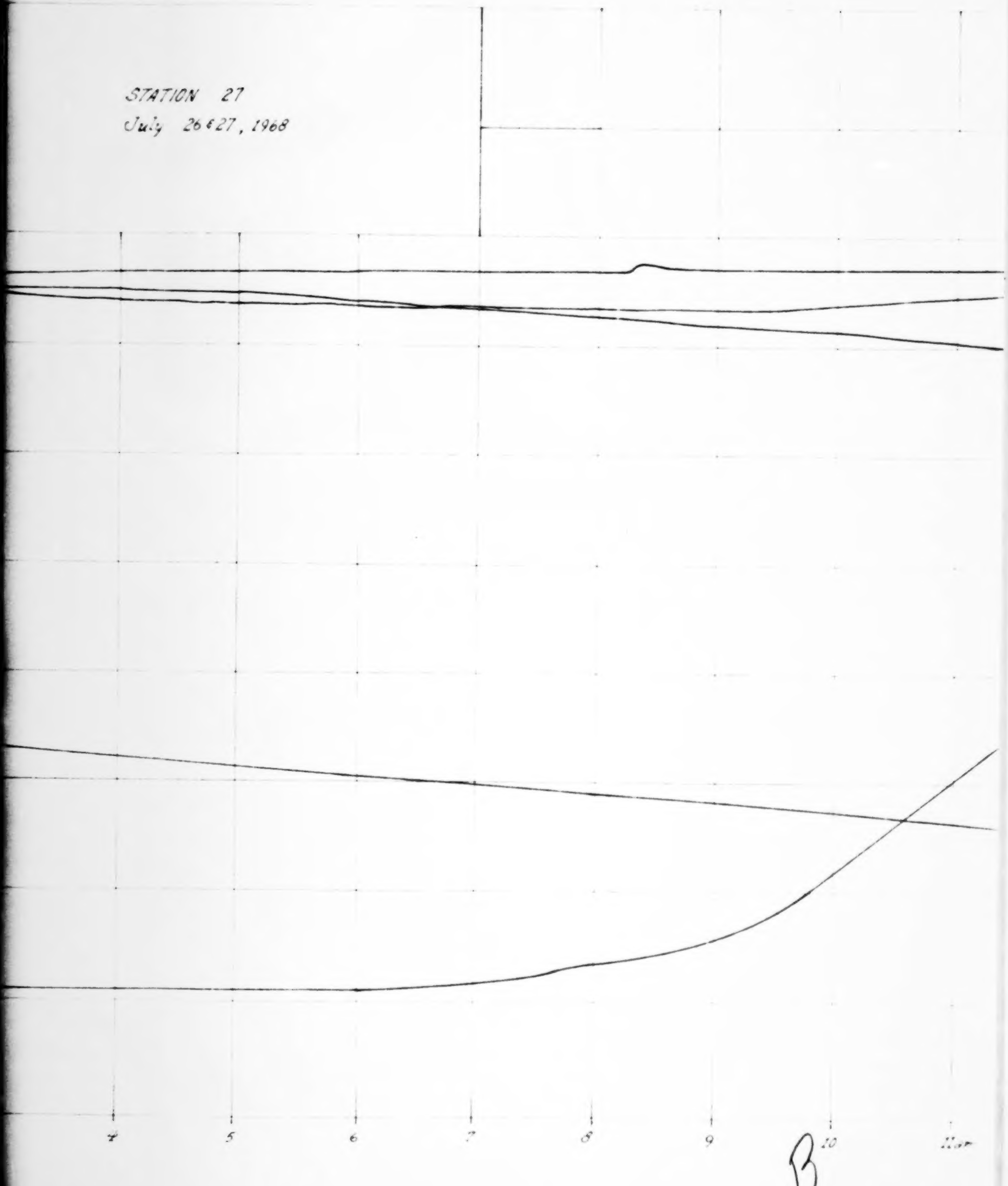

STATION 27
June 1, 1968
COND. & pH Inoperative
10
9
8
7
6
5
4
3
2
1
0
TEMP.
°F (÷10)
D.O.
166 cfs
peak flow
FLOW
(÷10²)
10 am
11
12
NOON
1 pm
2
3
4 pm


STATION 27
July 21 & 22, 1968
Brief, intense thunder storm over downtown about 4pm. No rain at W B
TEMP.°F (÷10)
pH
COND. (÷10²)
FLOW (÷10)
D.O.
10
9
8
7
6
5
4
3
2
1
0
11 pm
12 MIDNIGHT
1 am
2
3
4
4:30 am



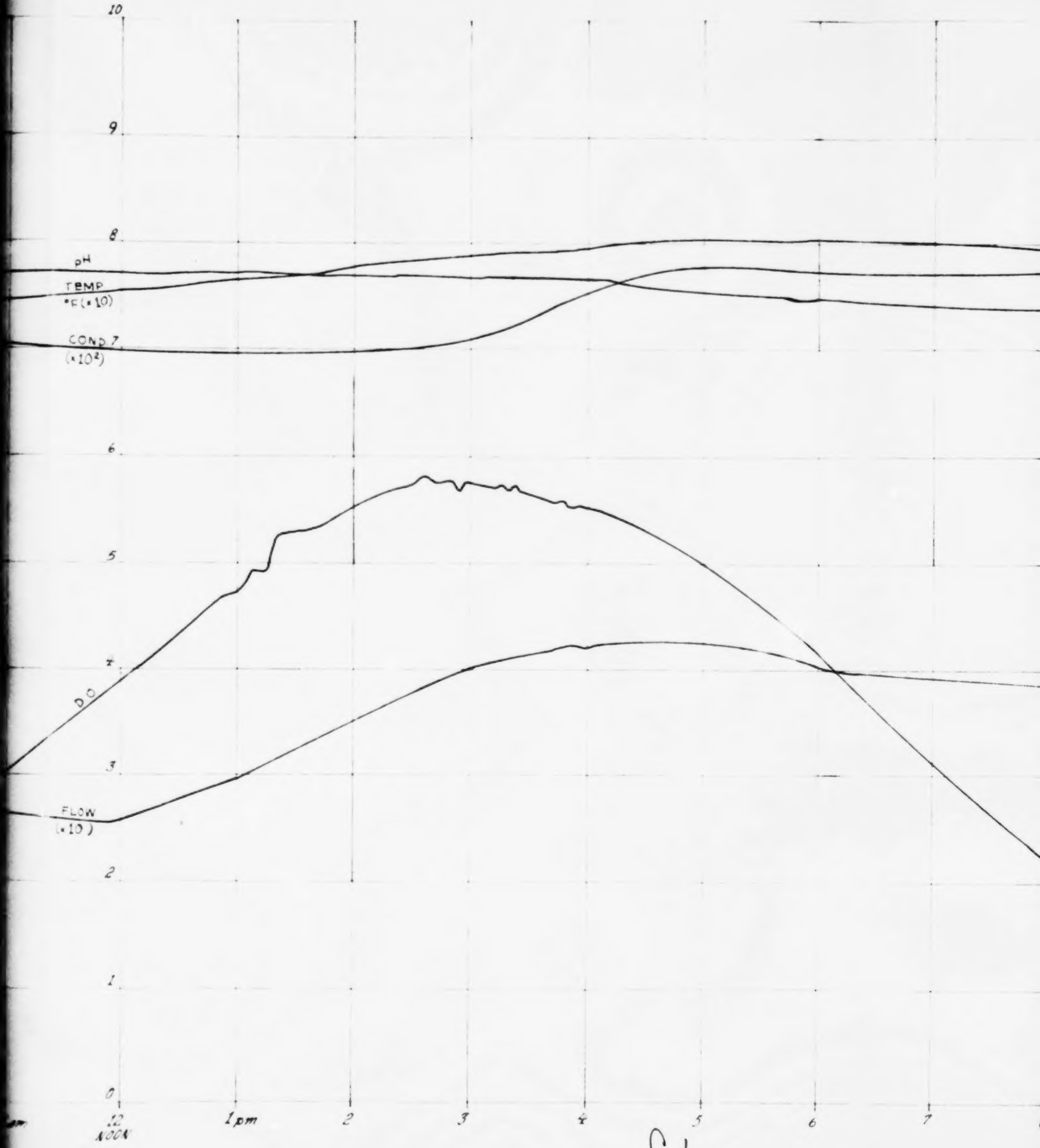
STATION 27
July 26 & 27, 1968

A

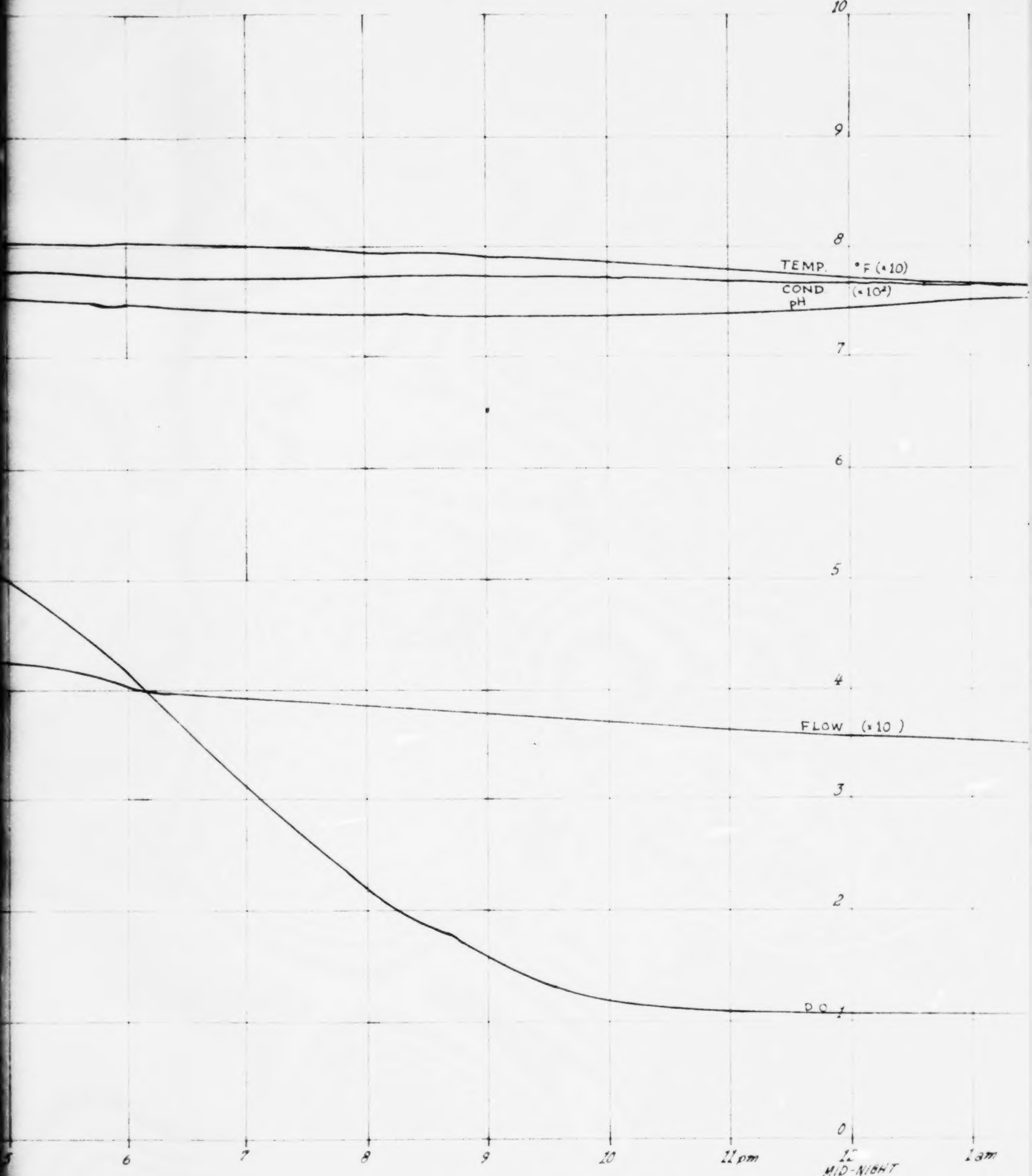


STATION 27
July 26 & 27, 1968

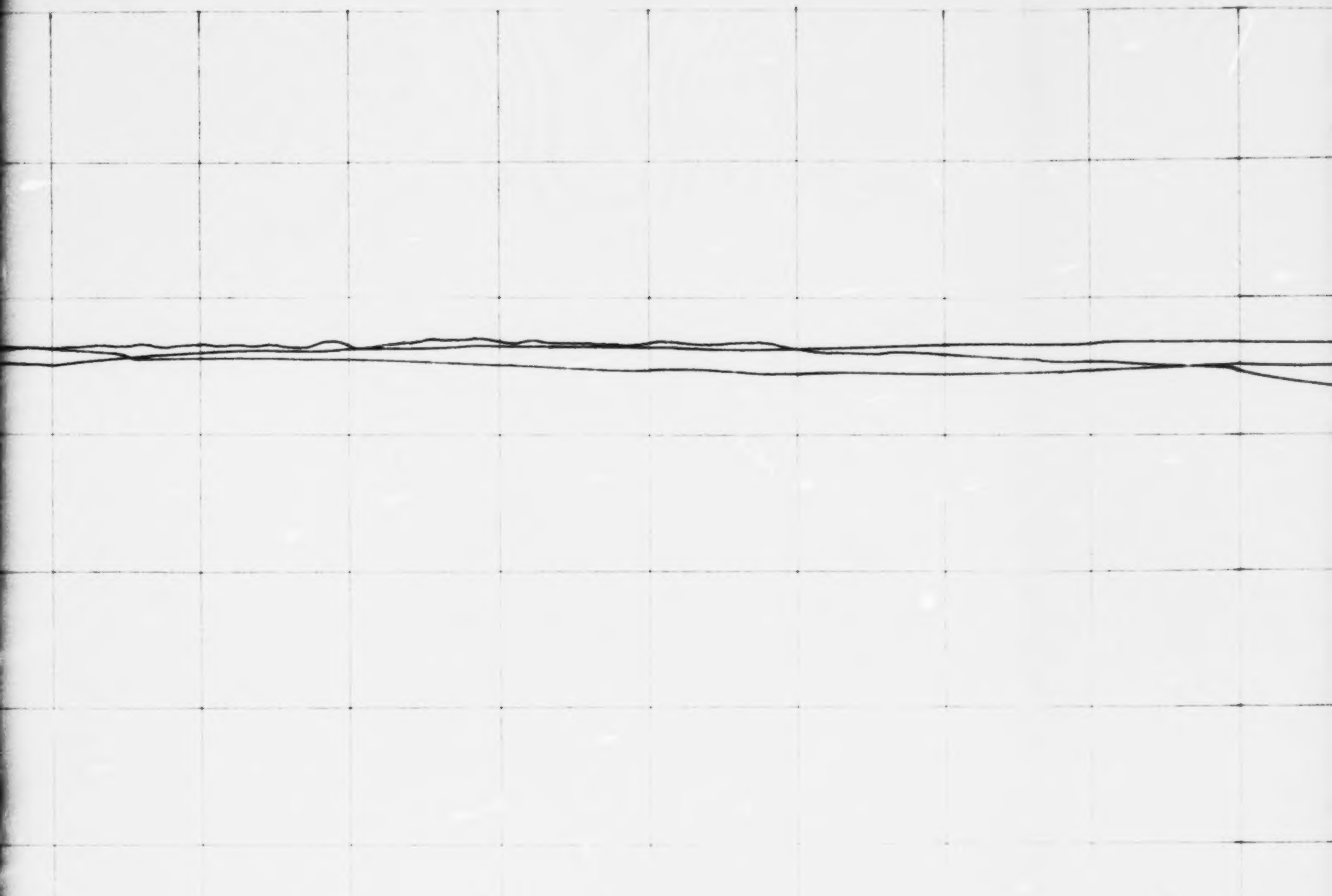
B

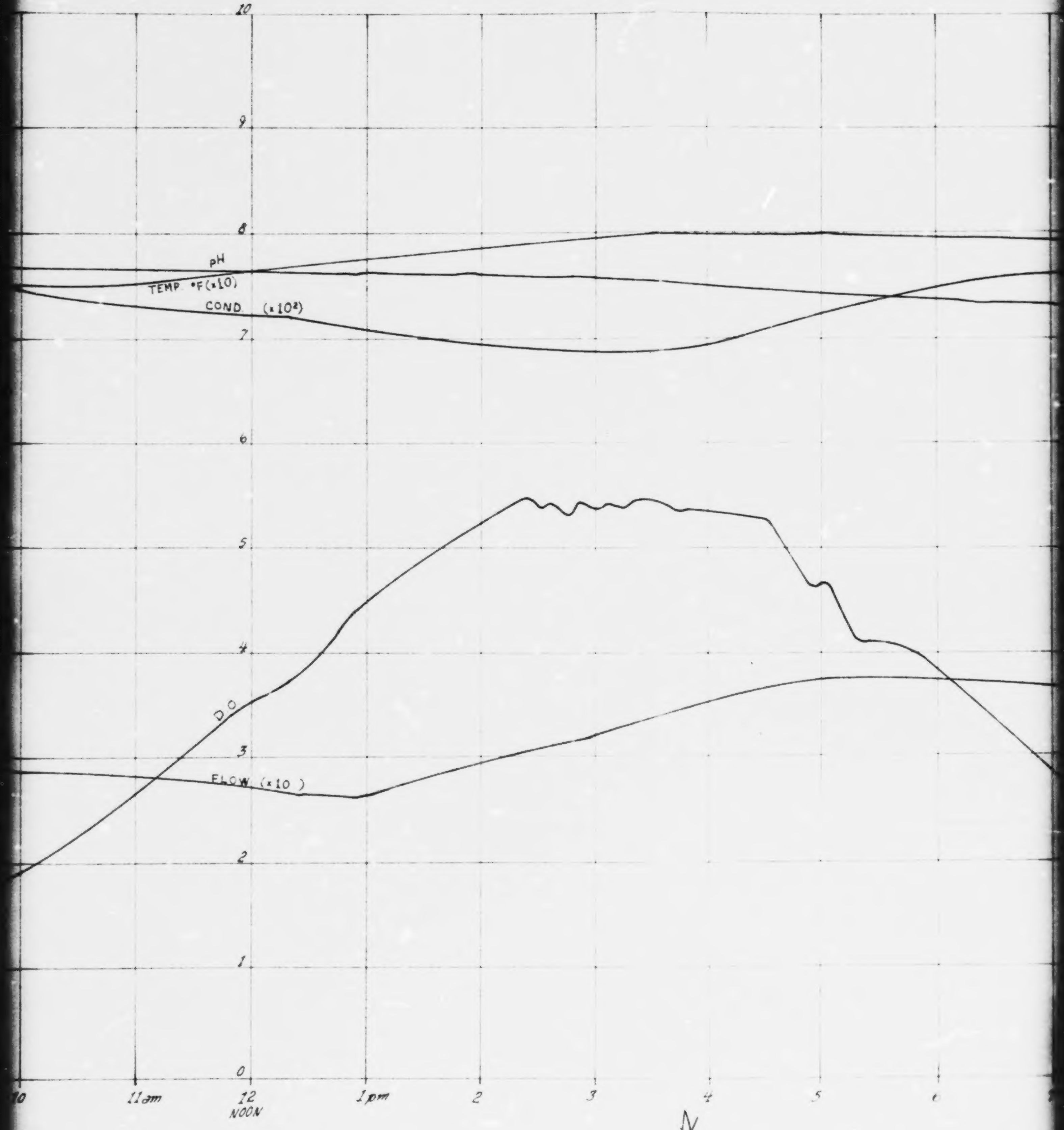

10
9
8
pH
TEMP
°F(×10)
COND 7
(×10²)
6
5
4
D.O.
3
FLOW
(×10)
2
1
0
12
NOON
1 pm
2
3
4
5
6
7

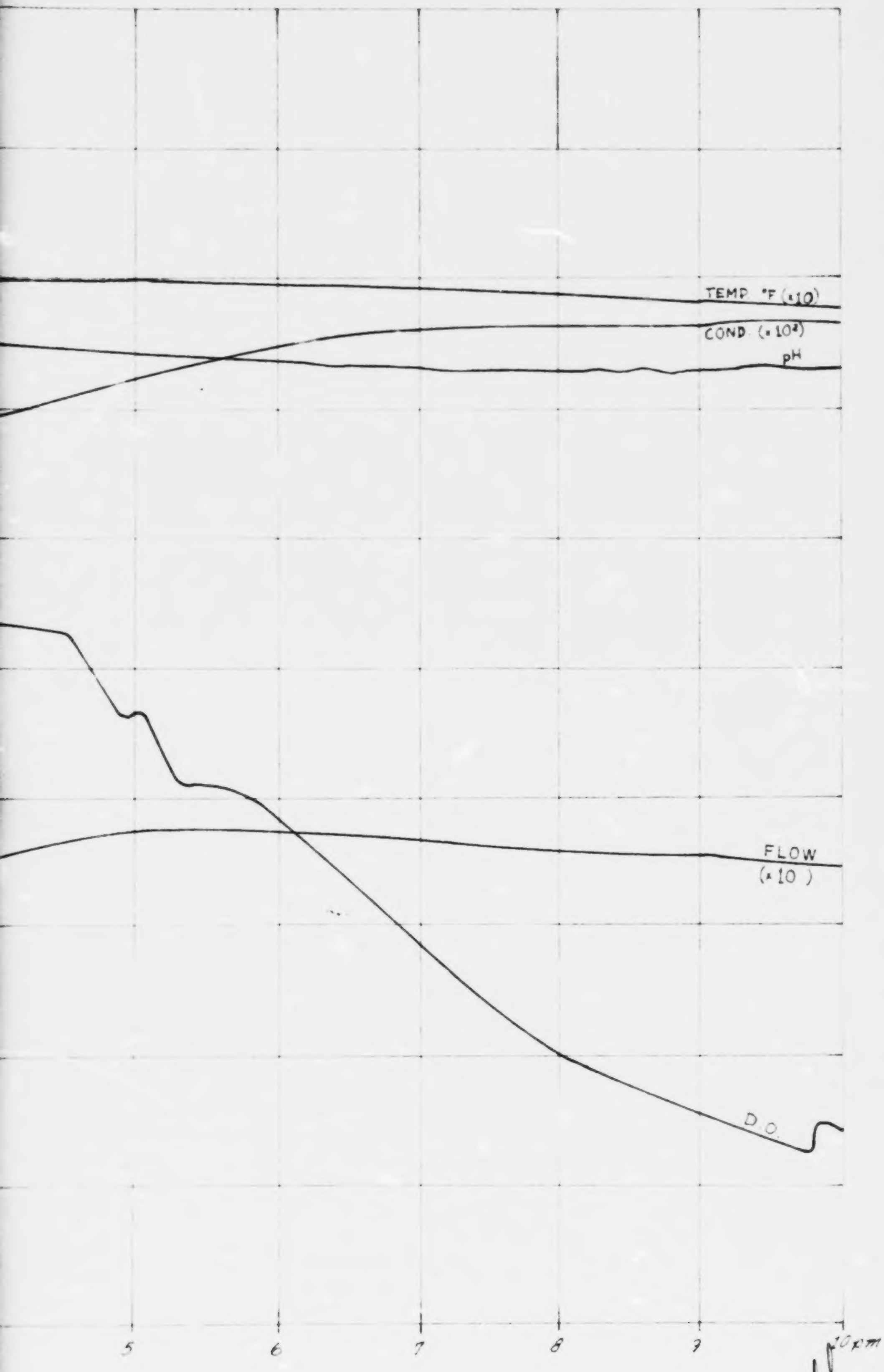
C

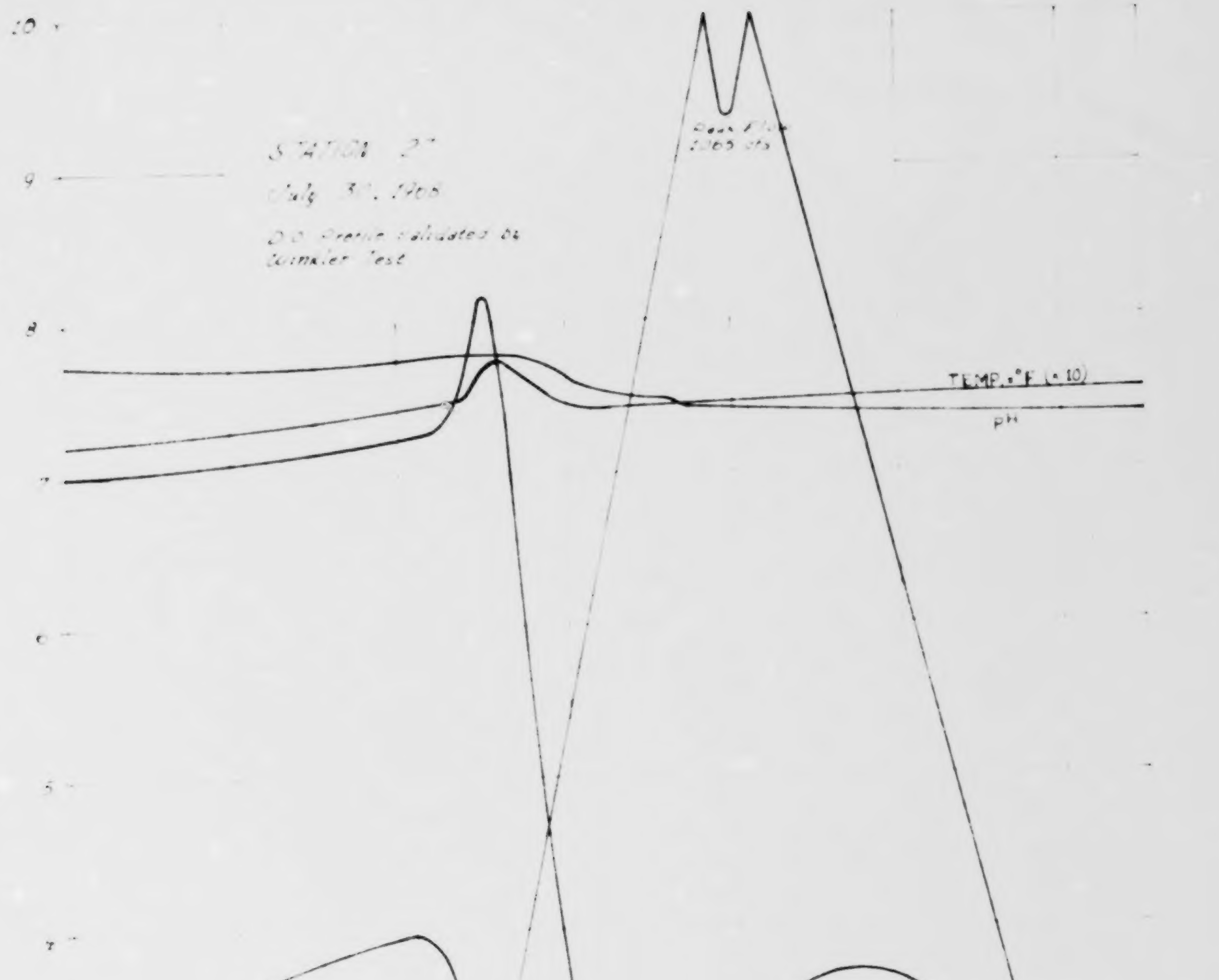

10
9
8
7
6
5
4
3
2
1
0
TEMP. °F (×10)
COND (×10²)
pH
FLOW (×10)
D.O.
6
7
8
9
10
11 pm
12
MID-NIGHT
1 am

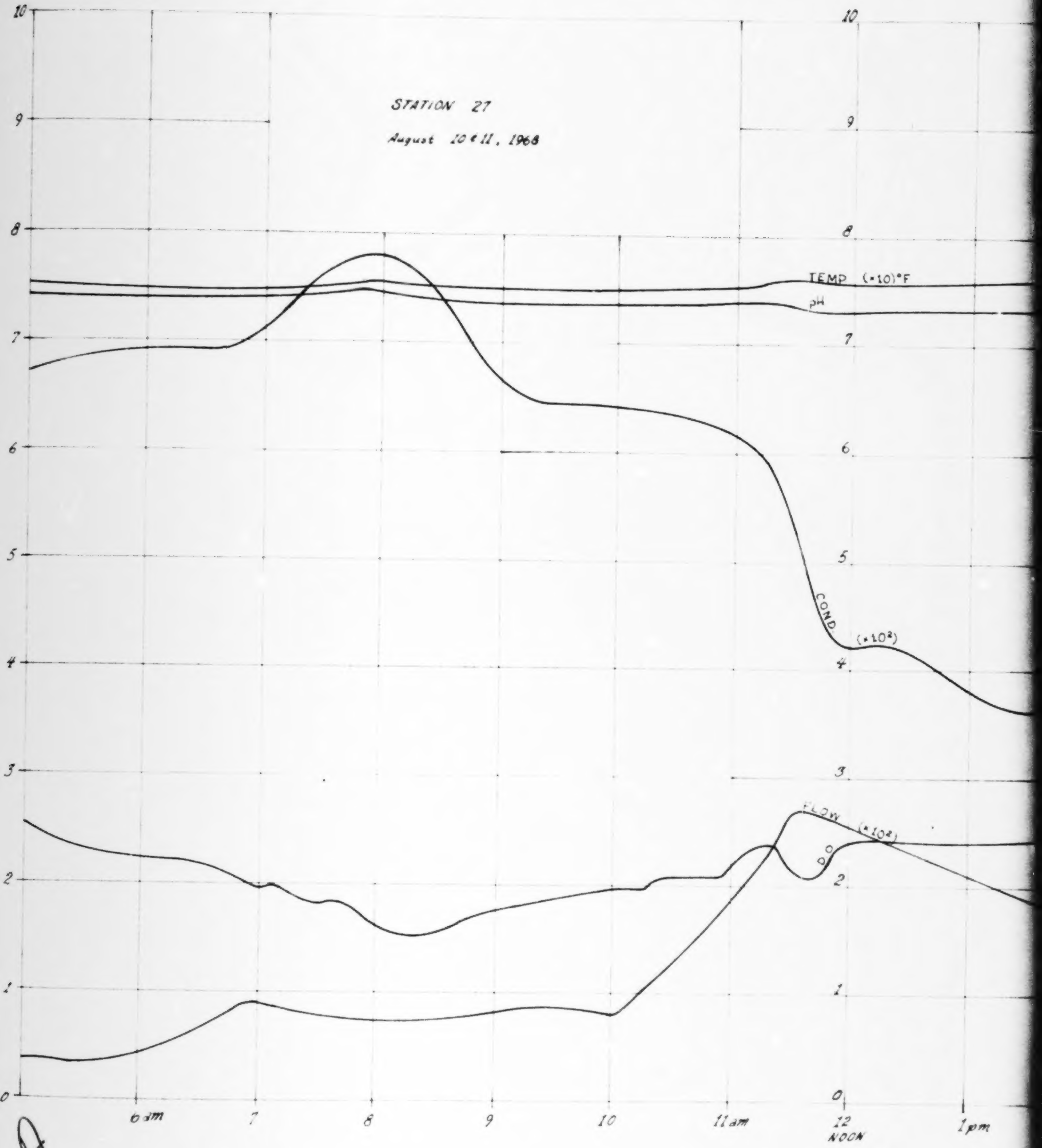
D


2
3
4
5
6
7
8
9
10
V


10
9
8
7
6
5
4
3
2
1
0
pH
TEMP. °F(×10)
COND. (×10²)
D.O.
FLOW (×10)
10
11am
12
NOON
1pm
2
3
4
5
6


TEMP °F (×10)
COND (×10²)
pH
FLOW (×10)
D.O.
5
6
7
8
9
10 pm

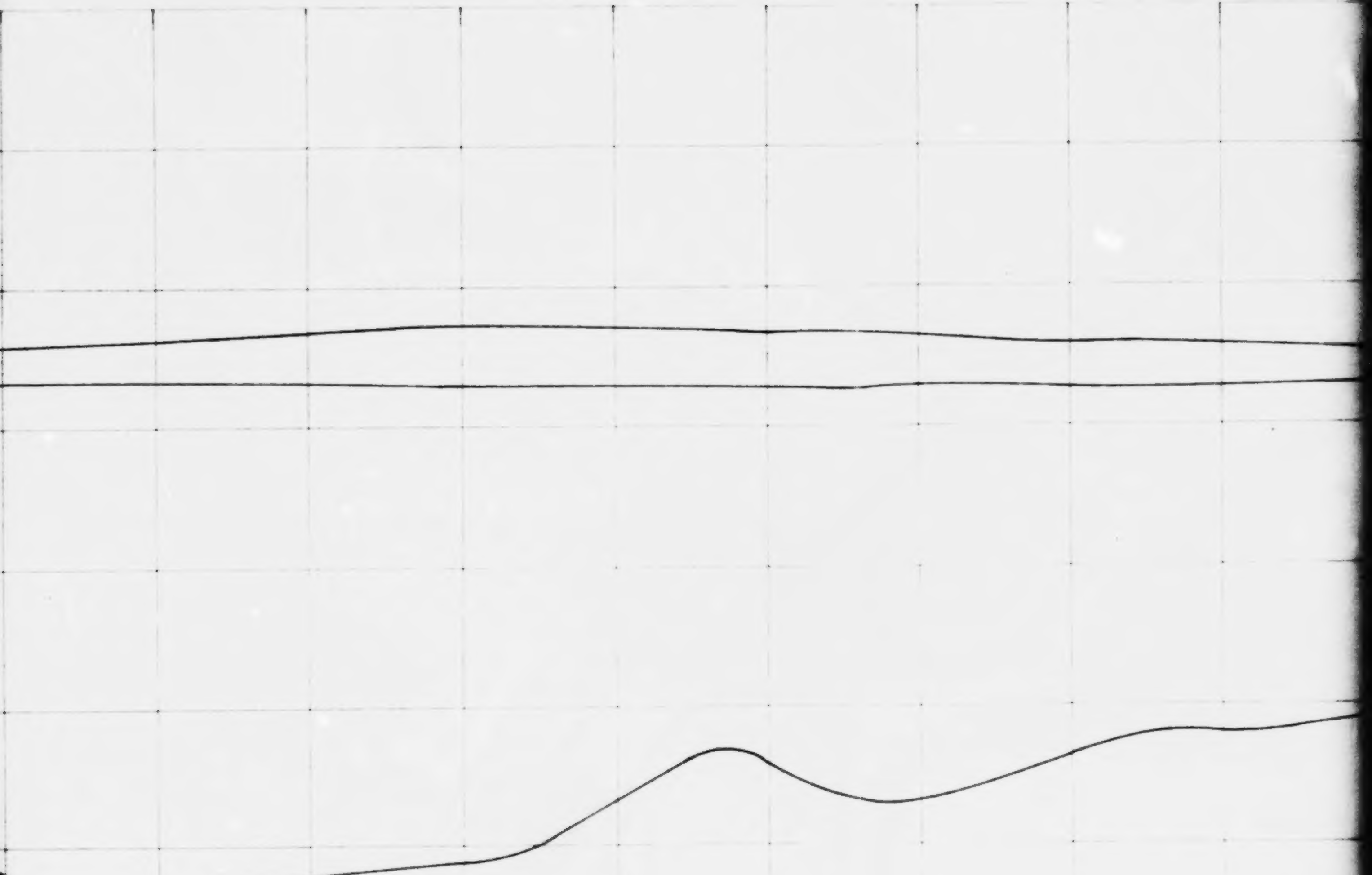

STATION 2
July 30, 1968
D.O. Profile validated by Winkler Test
Peak Flow 1065 cfs
TEMP. °F (÷10)
pH
D.O.
COND (×10²)
FLOW (×10²)
10
9
8
7
6
5
4
3
2
1
0
3 pm
4
5
6
7
8
8:30 pm



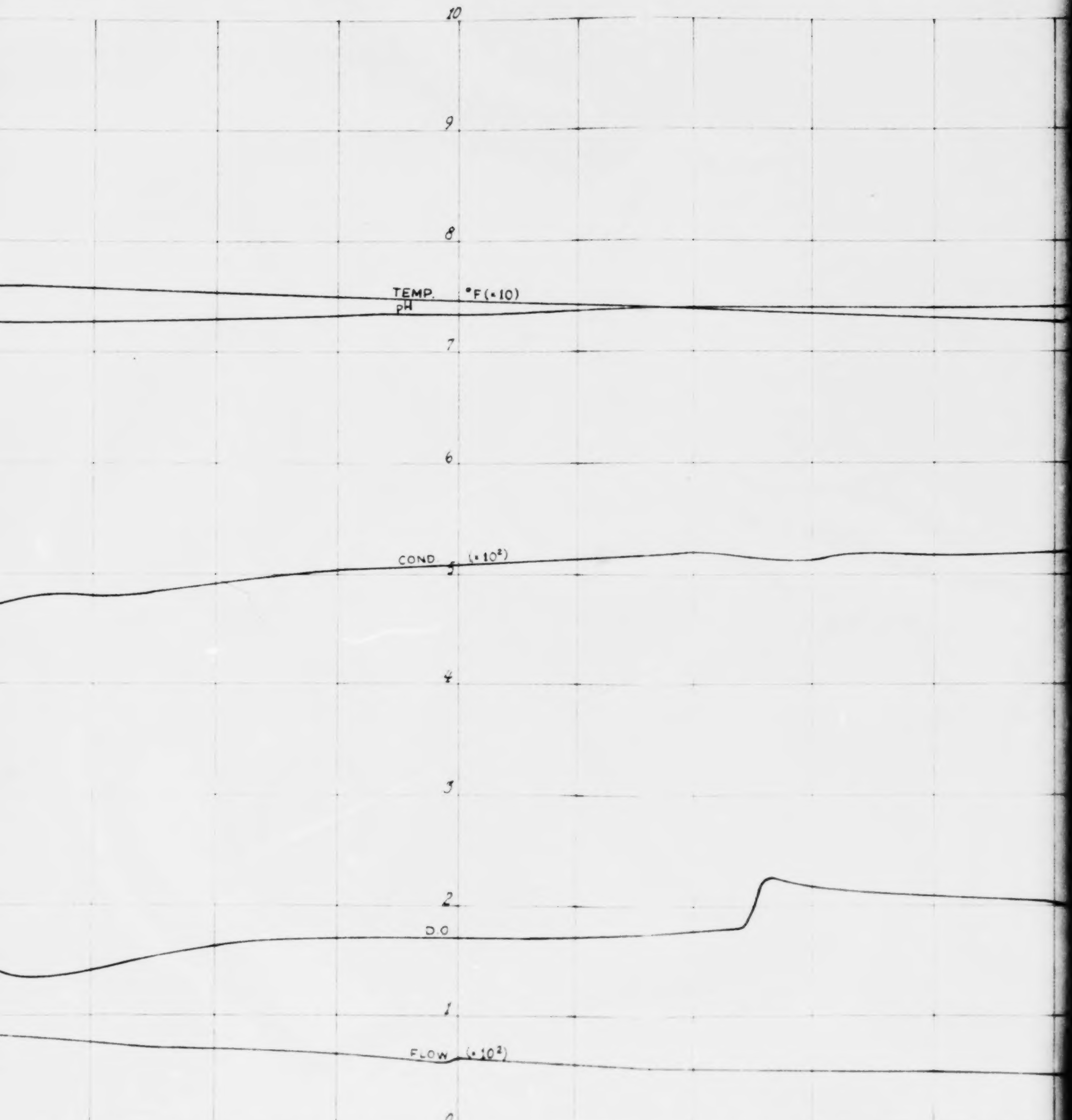
STATION 27

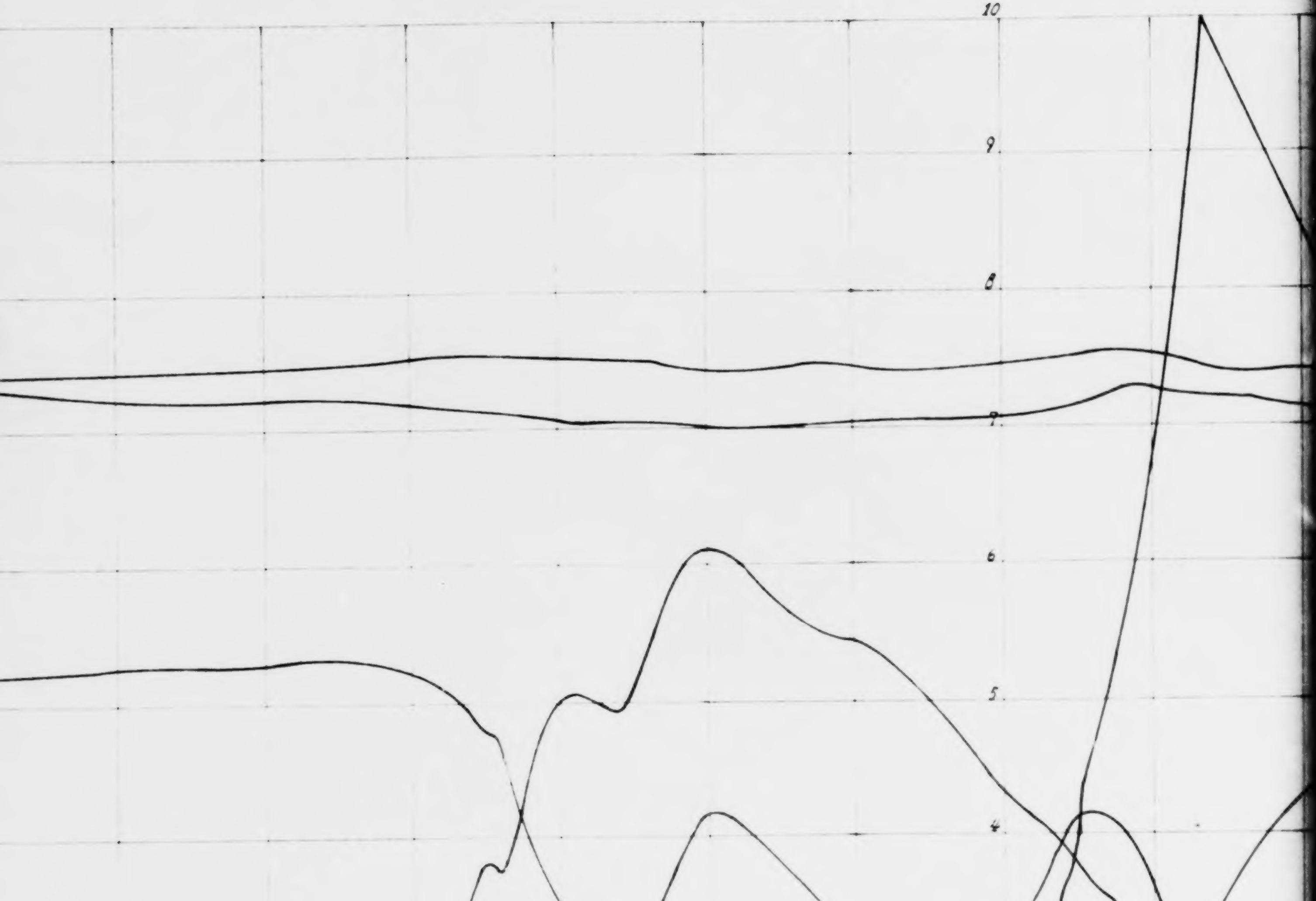
August 10 & 11, 1968

A

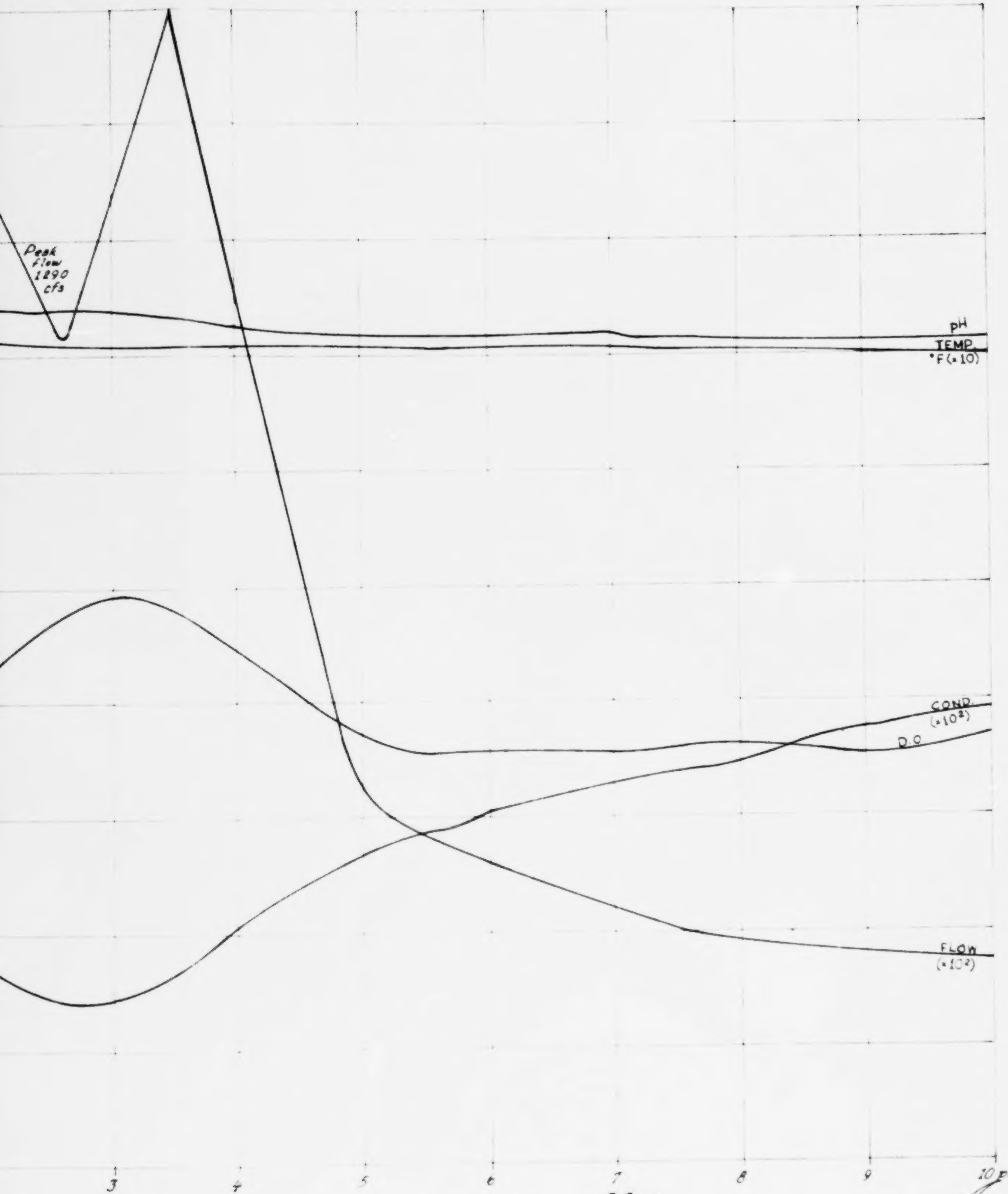


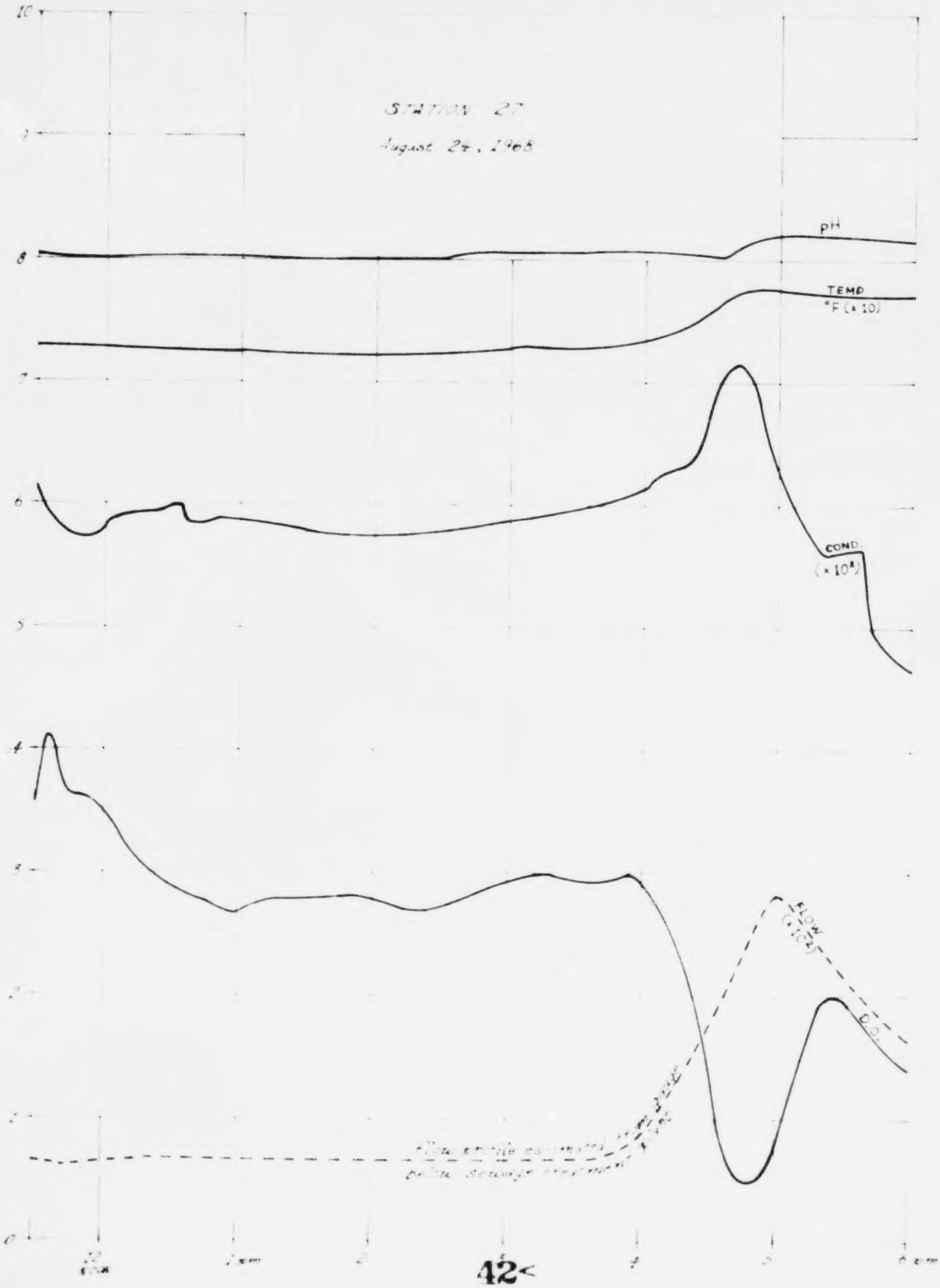
B


10
9
8
TEMP. °F (×10)
pH
7
6
COND (×10²)
5
4
3
2
D.O
1
FLOW (×10²)
0
9
10
11pm
12
MID-NIGHT
1am
2
3
4
5



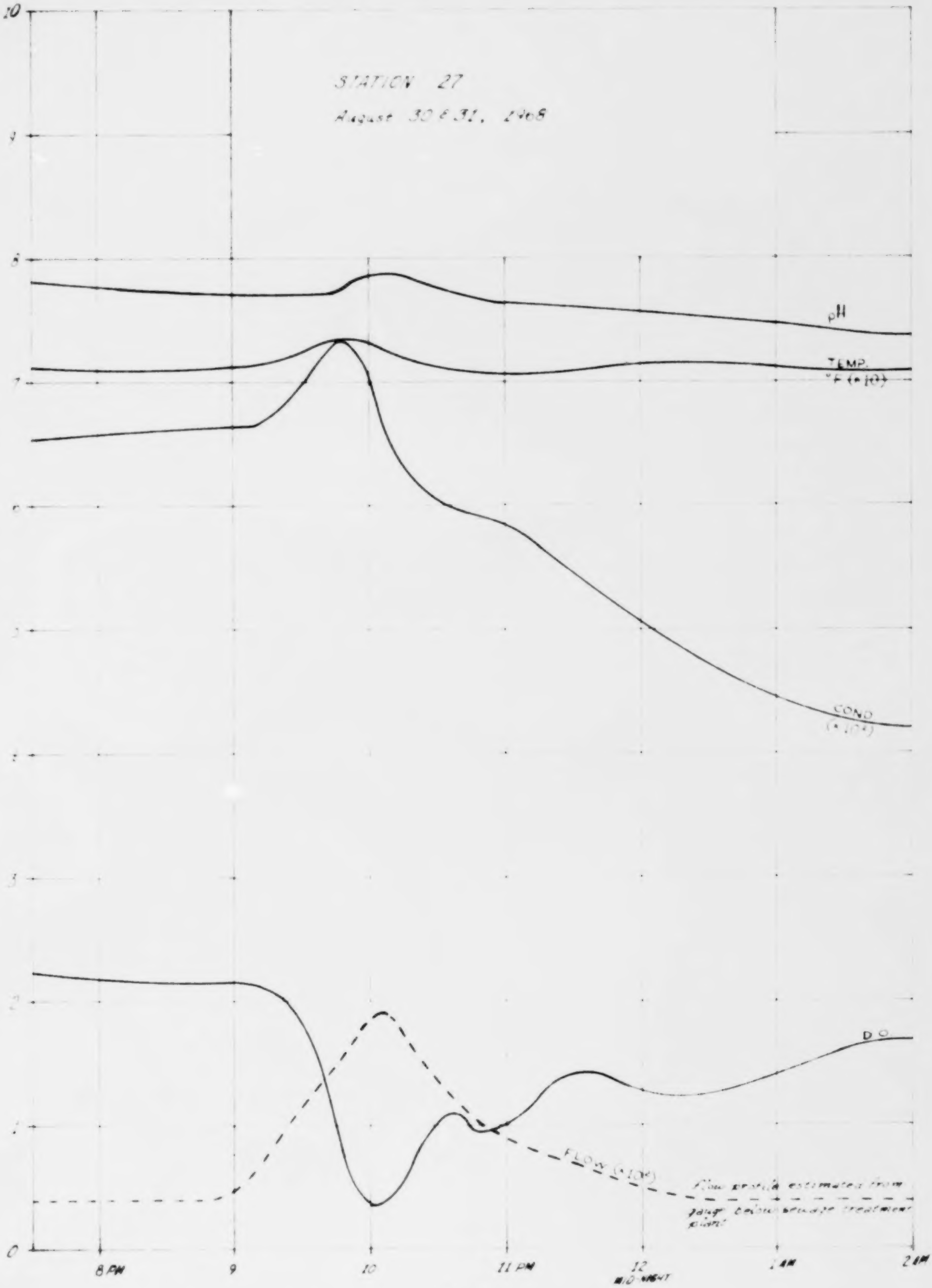
10
9
8
7
6
5
4
3
2
1
0
6
7
8
9
10
11am
12
NOON
1pm

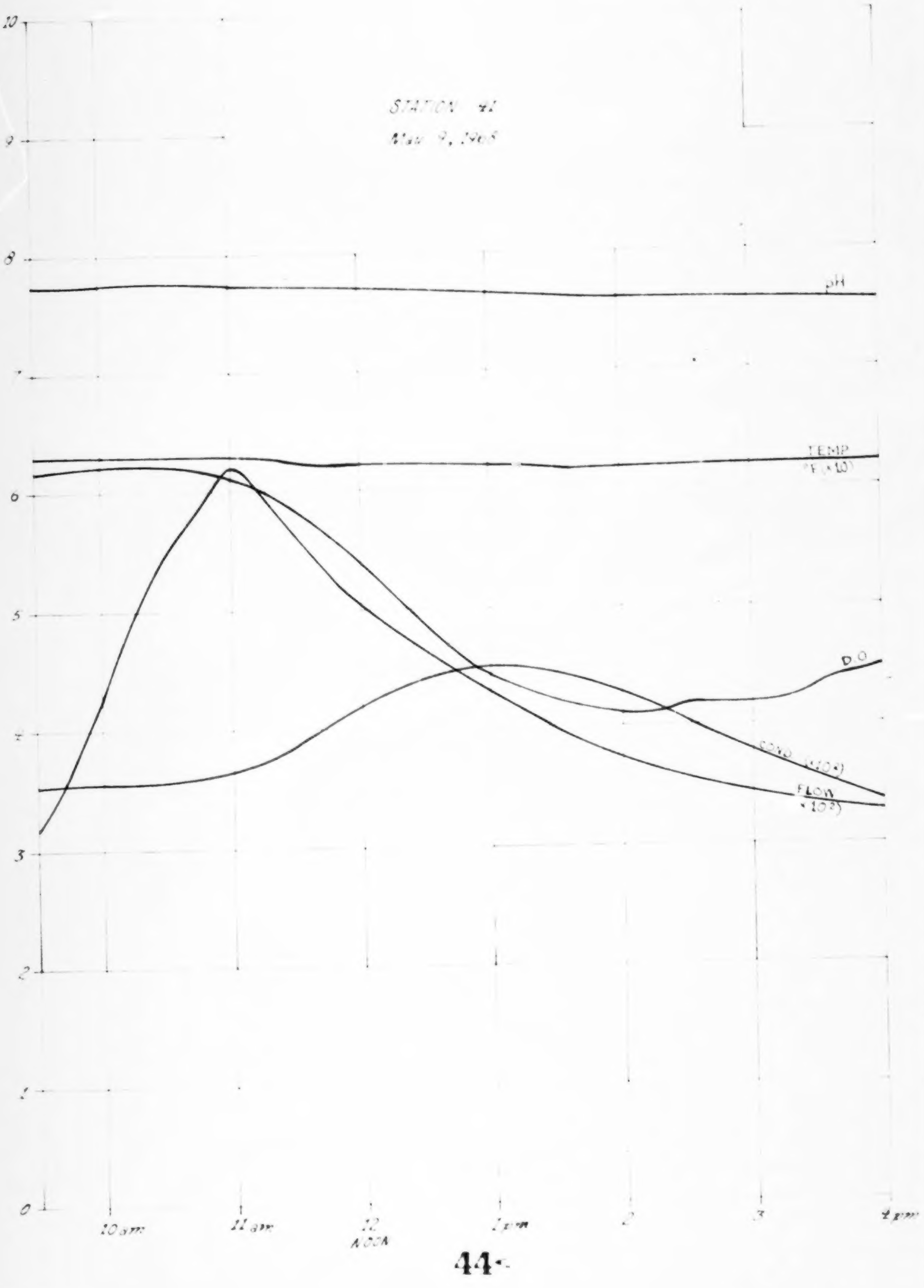

Peak flow 1290 cfs
pH
TEMP. °F (÷10)
COND. (÷10²)
D.O
FLOW (÷10²)
3
4
5
6
7
8
9
10 pm

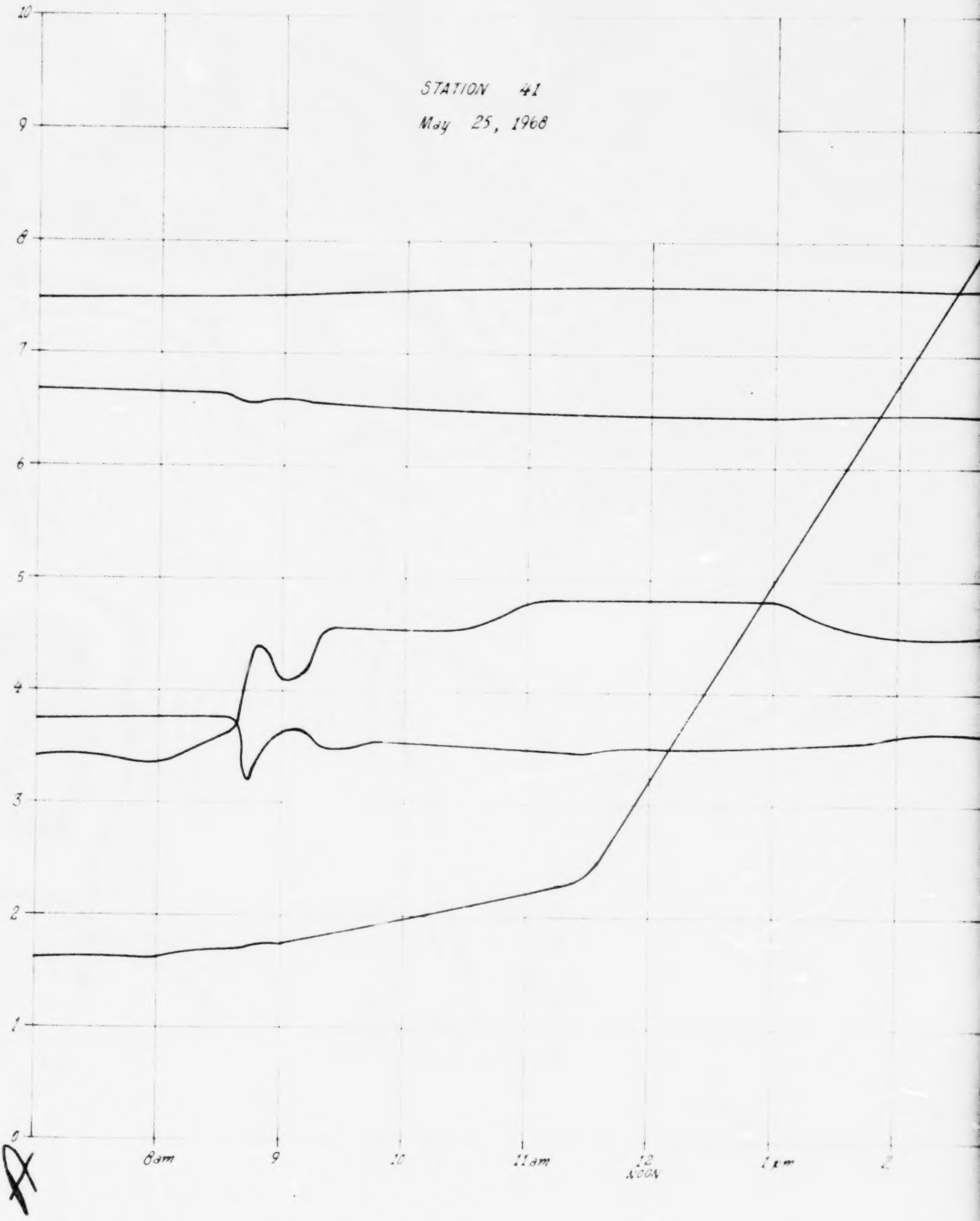


STATION 27

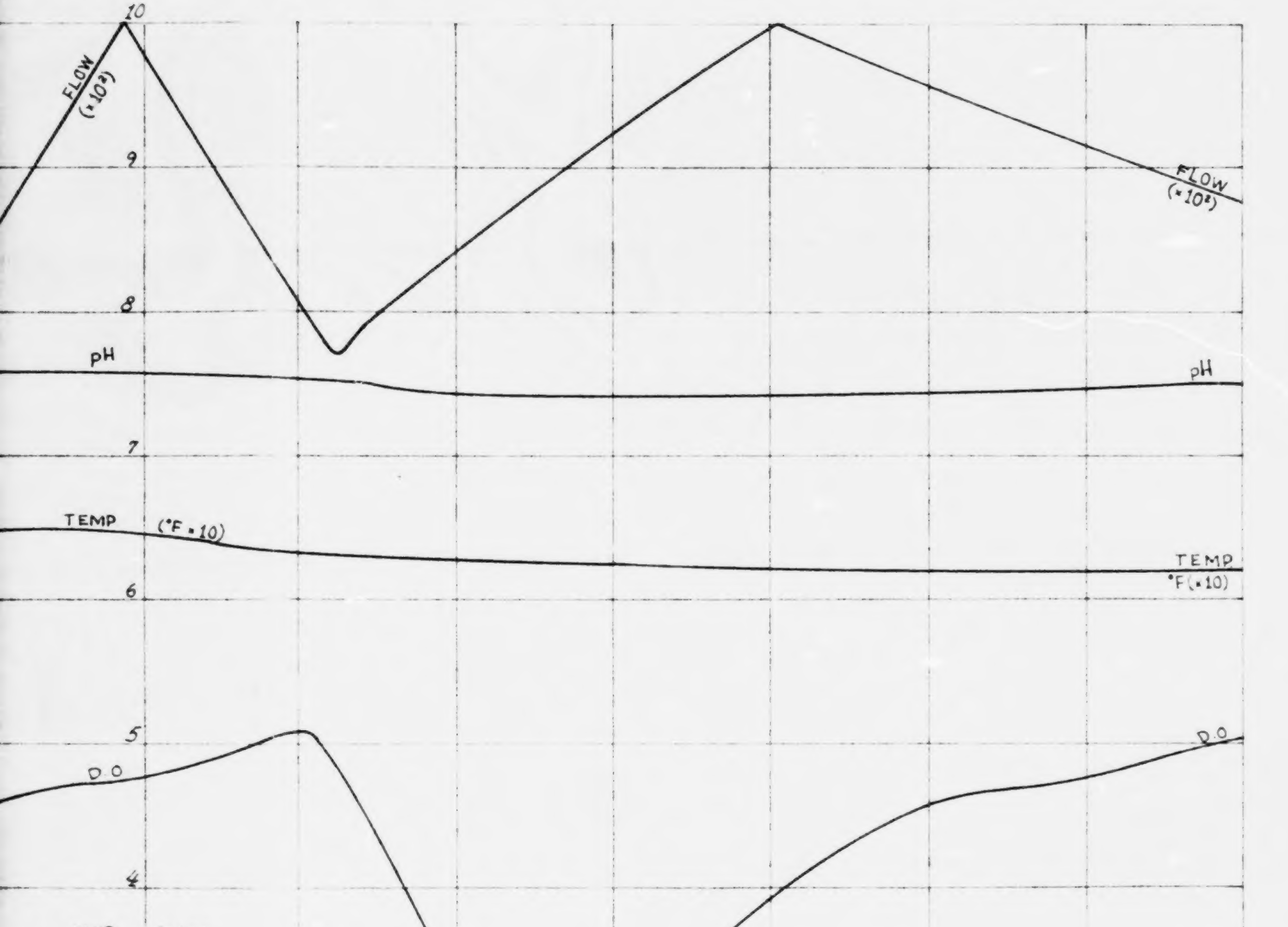
August 24, 1968

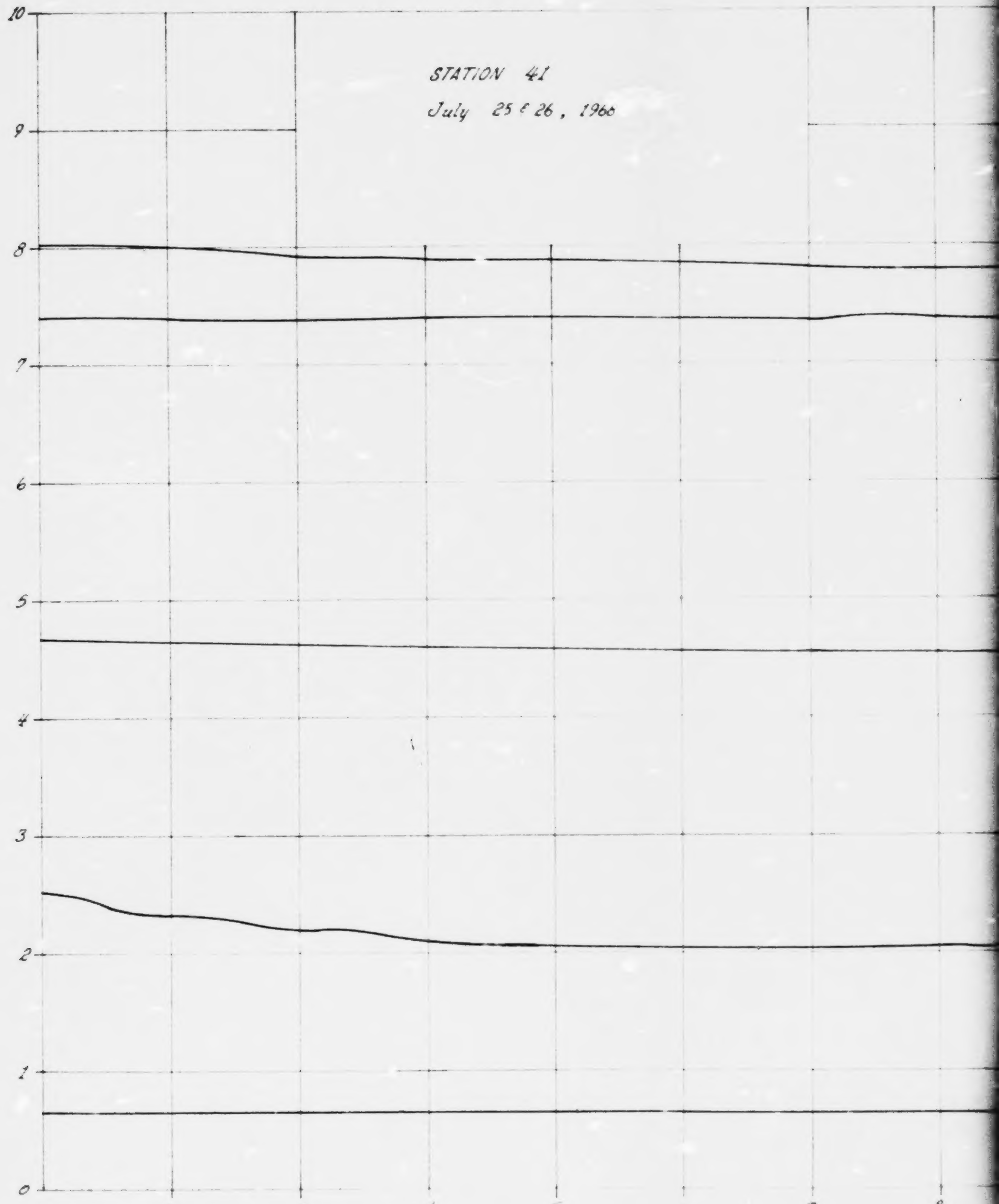

STATION 27
August 30 & 31, 1968
10
9
8
7
6
5
4
3
2
1
0
pH
TEMP. °F (×10)
COND ($\times 10^4$)
D.O.
FLOW ($\times 10^2$)
Flow profile estimated from gauge below sewage treatment plant
8 PM
9
10
11 PM
12 MID-NIGHT
1 AM
2 AM


STATION 41
May 9, 1968
10
9
8
7
6
5
4
3
2
1
0
pH
TEMP °F (×10)
D.O.
COND (×10²)
FLOW (×10²)
10 am
11 am
12 NOON
1 pm
2
3
4 pm



STATION 41
May 25, 1968


FLOW (×10²)
10
9
8
pH
7
TEMP (°F ×10)
6
5
D.O
4
COND (×10²)
3
2
1
0
4
5
6
7
8
9
10
11 pm
FLOW (×10²)
pH
TEMP °F(×10)
D.O
COND. (×10²)

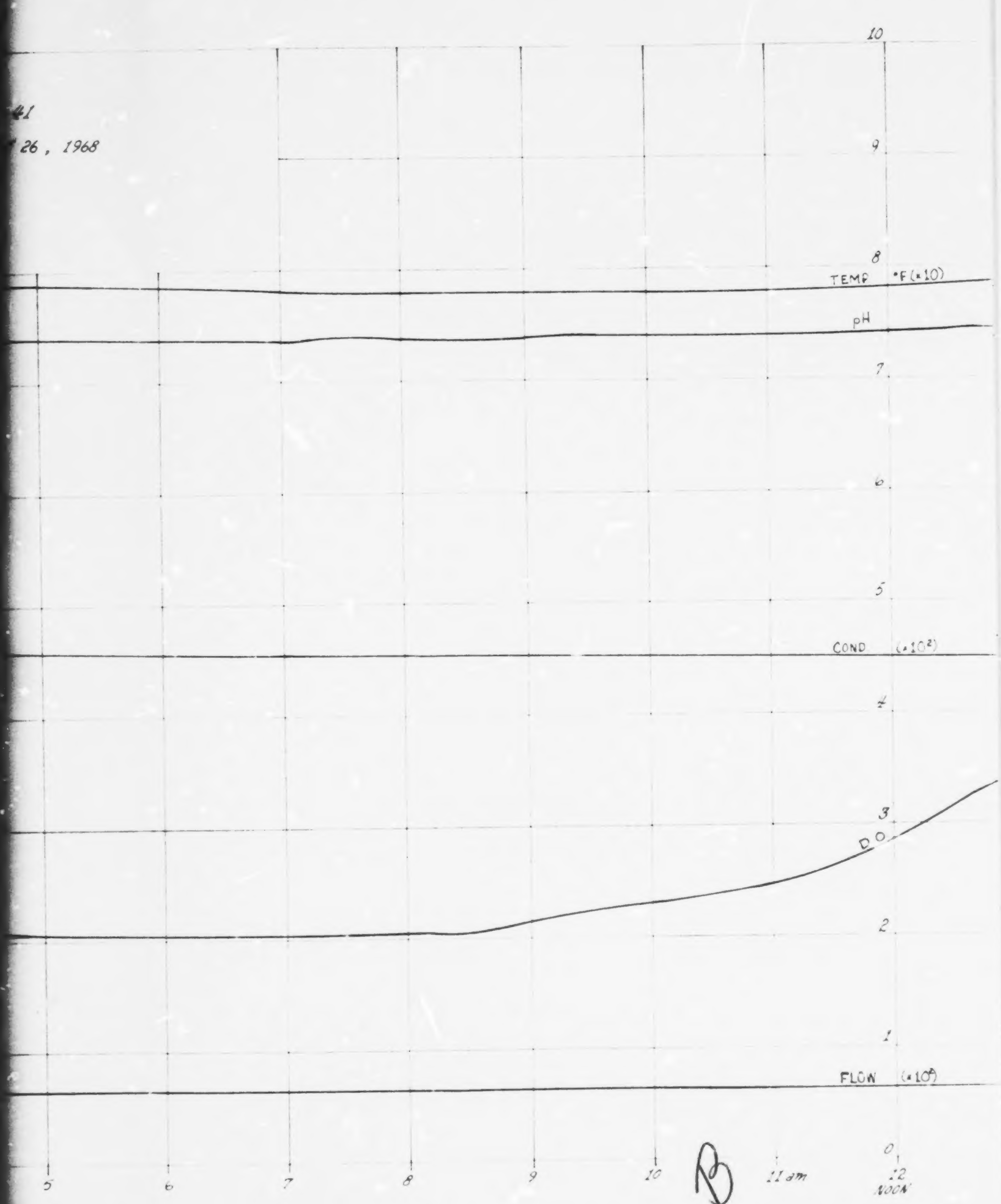


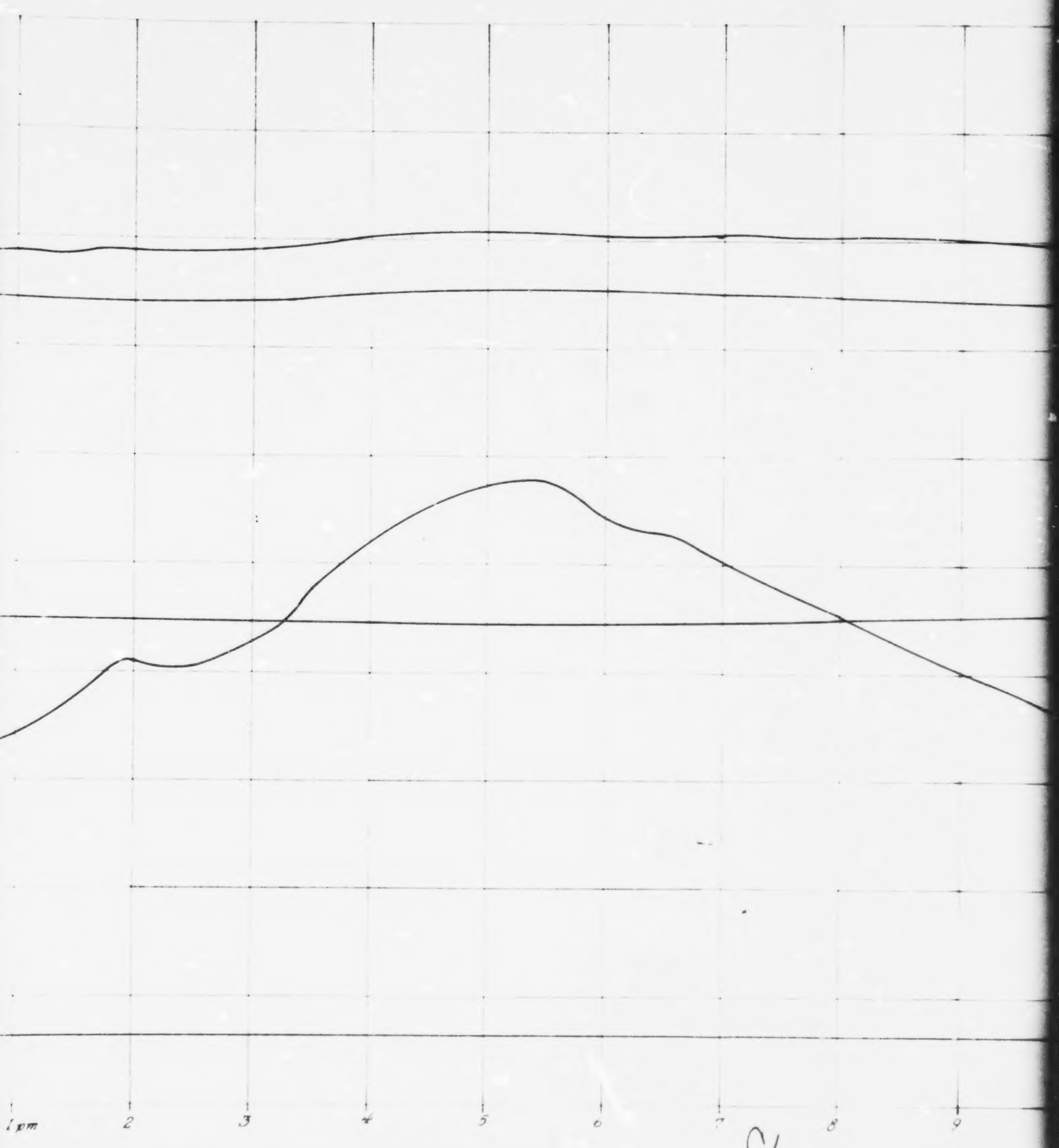
STATION 41

July 25 & 26, 1960

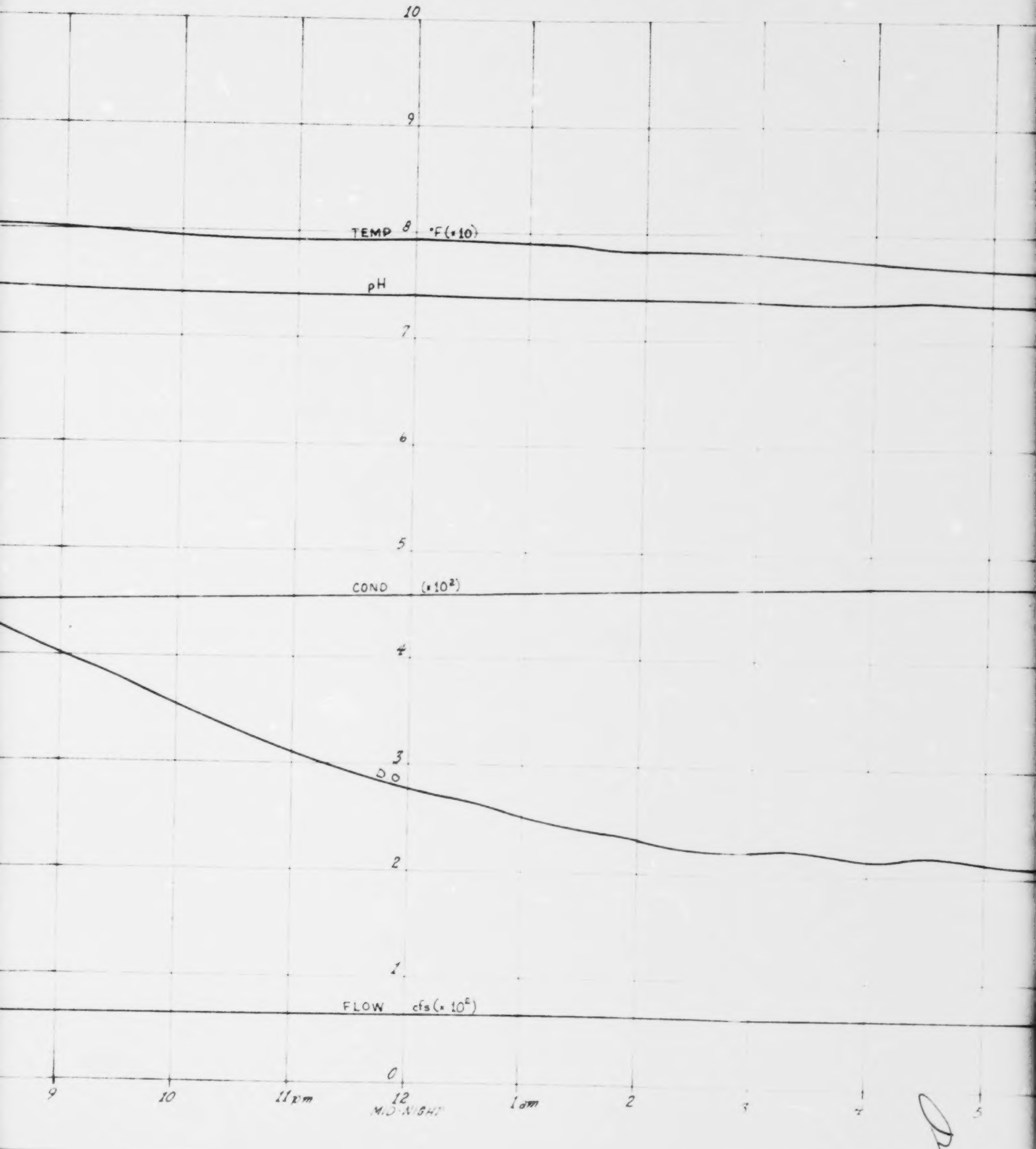
41

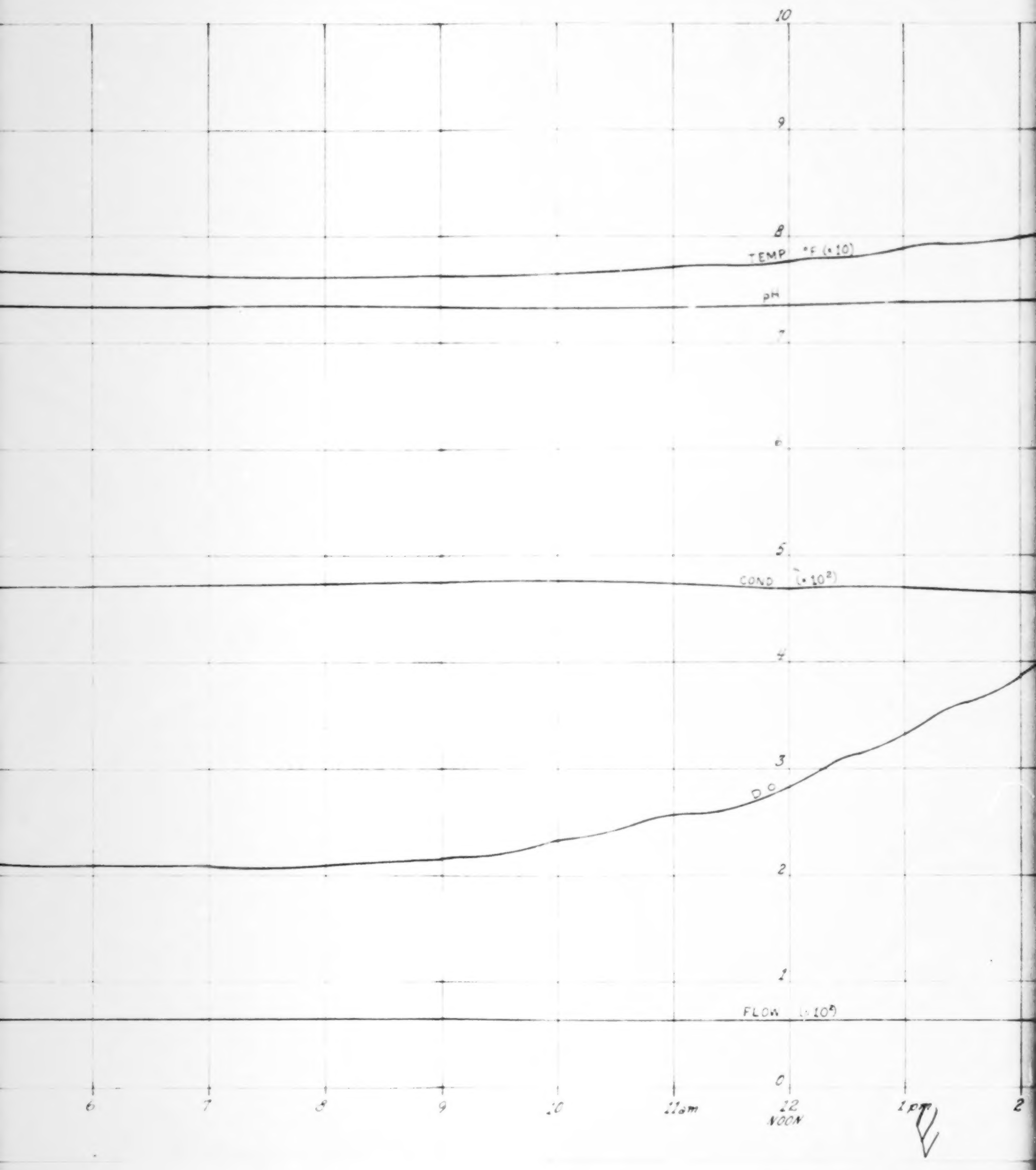
26 , 1968

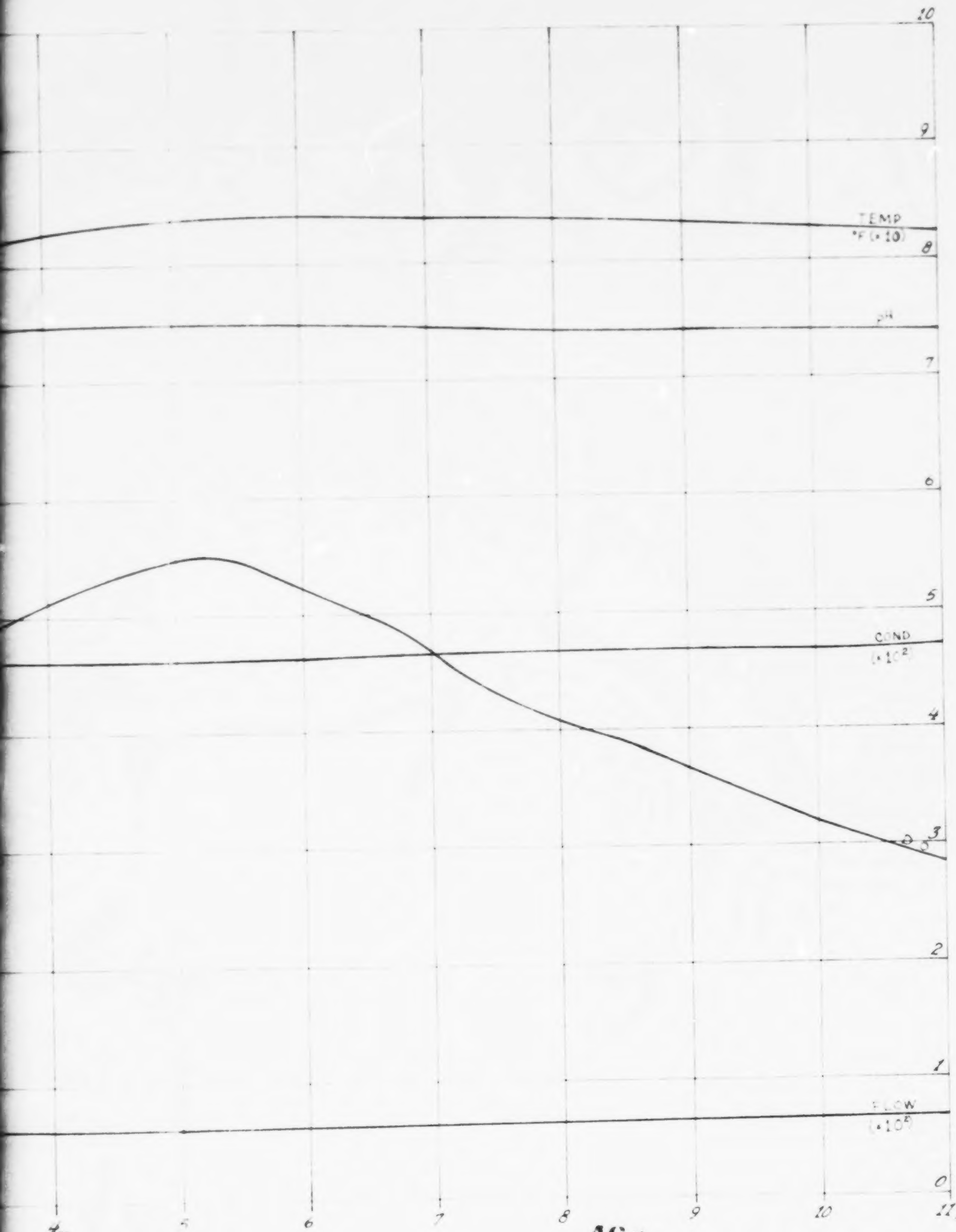

10
9
8
TEMP °F (×10)
pH
7
6
5
COND (×10^2)
4
3
D.O.
2
1
FLOW (×10^4)
0
5
6
7
8
9
10
B
11 am
12
NOON

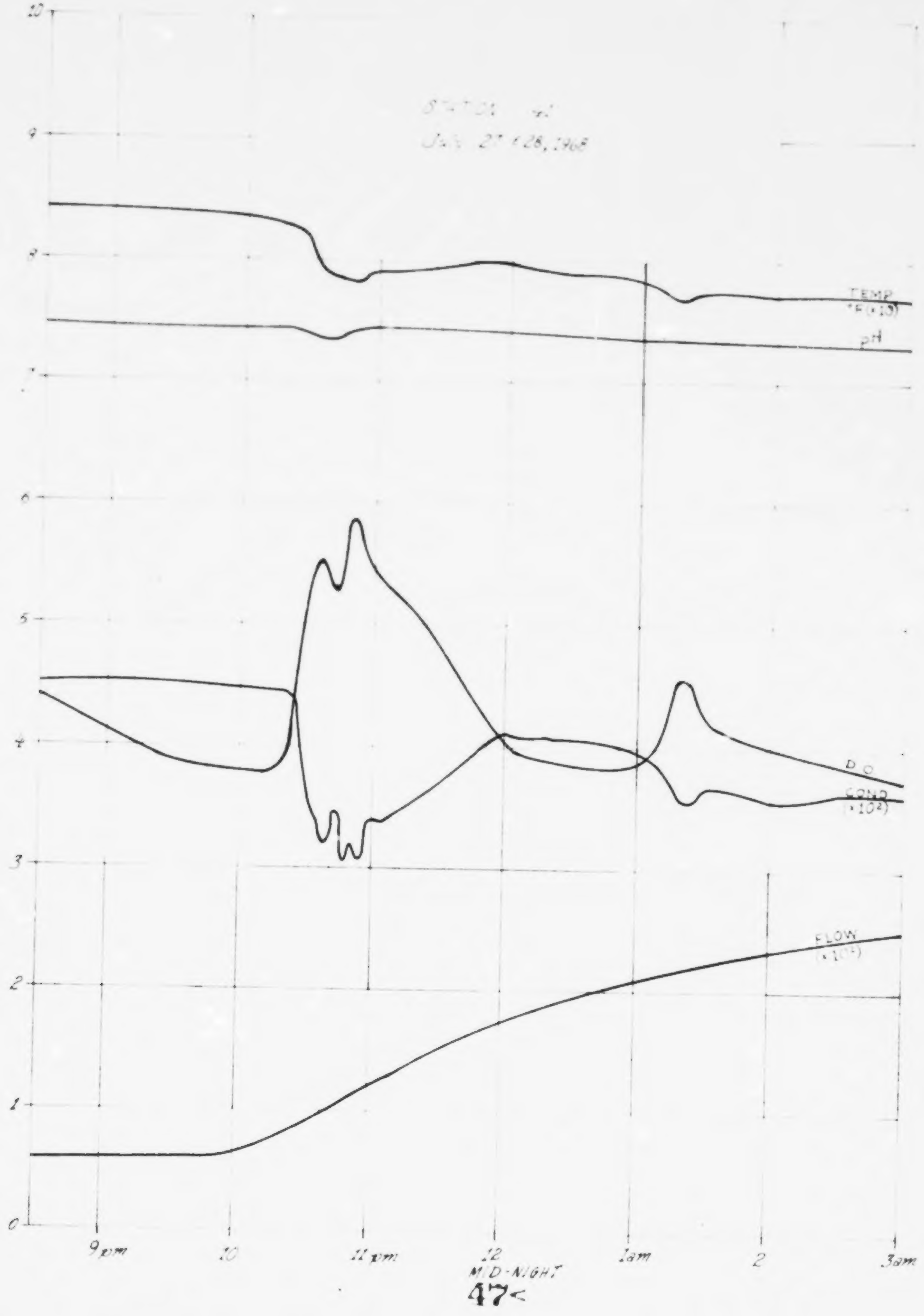


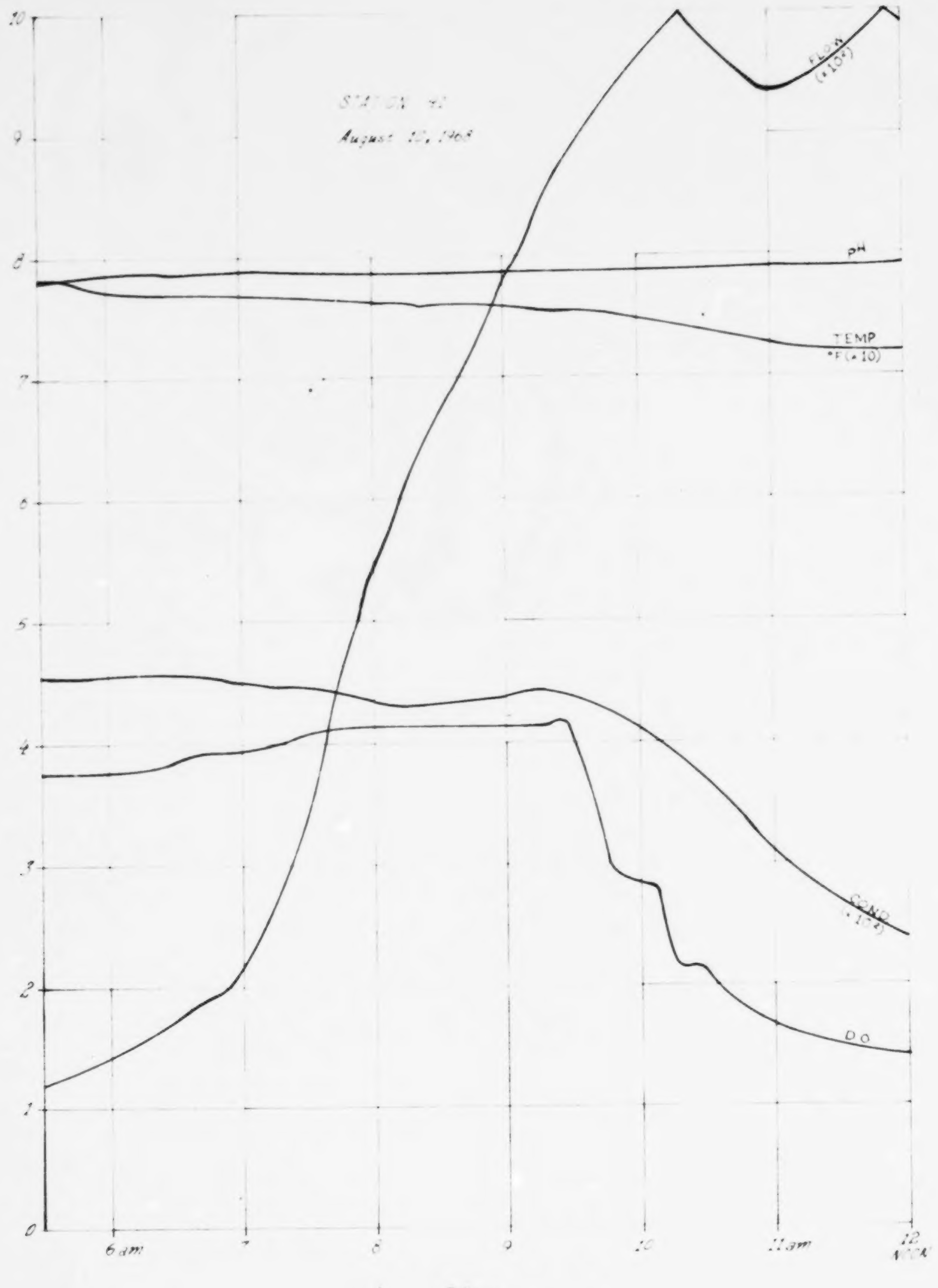
C

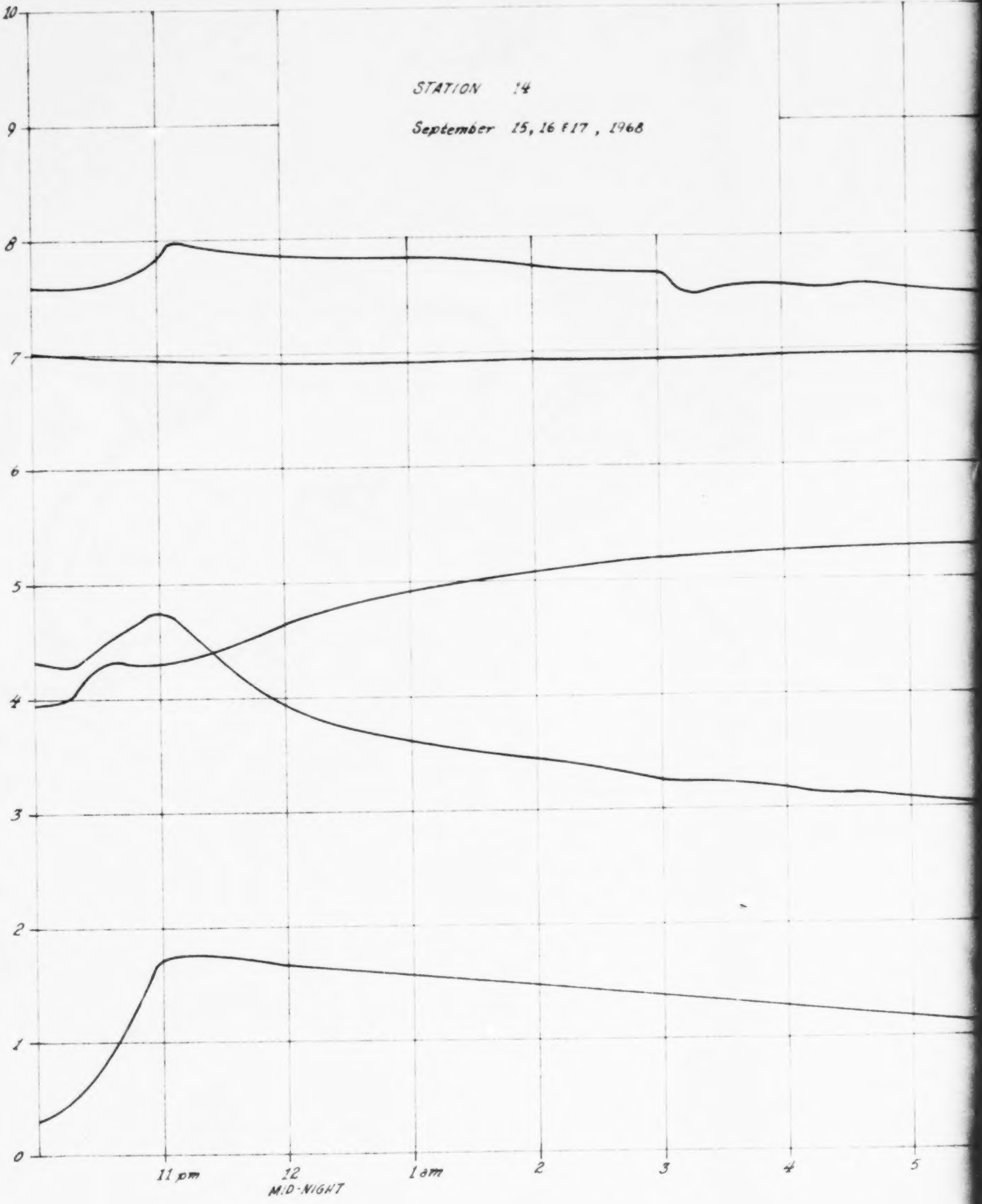

10
9
TEMP 8 °F (×10)
pH
7
6
5
COND (×10²)
4
3
DO
2
1
FLOW cfs (× 10²)
0
9
10
11pm
12
MID-NIGHT
1am
2
3
4
5


10
9
8
TEMP °F (·10)
pH
7
6
5
COND (·10^2)
4
3
D O
2
1
FLOW (·10^9)
0
6
7
8
9
10
11am
12
NOON
1pm
2


10
9
TEMP
°F (×10)
8
pH
7
6
5
COND
(×10²)
4
DO
3
2
1
FLOW
(×10⁵)
0
4
5
6
7
8
9
10
11 pm


STATION
July 27 & 28, 1968
10
9
8
7
6
5
4
3
2
1
0
TEMP
°F (×10)
pH
D.O.
COND
(×10²)
FLOW
(×10²)
9 pm
10
11 pm
12
MID-NIGHT
1 am
2
3 am

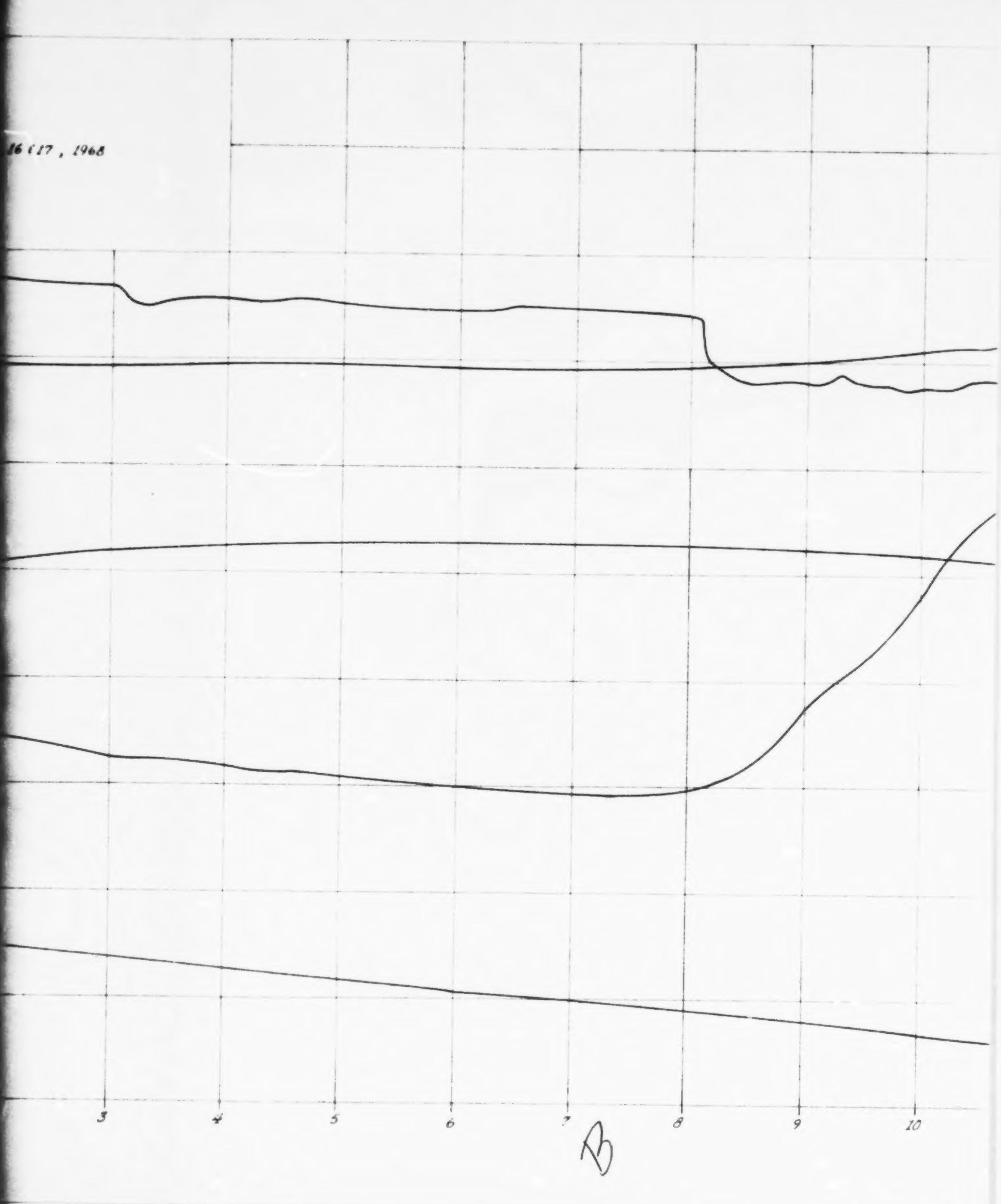

STATION 42
August 10, 1968
FLOW (×10²)
pH
TEMP °F (×10)
COND (×10²)
D O
10
9
8
7
6
5
4
3
2
1
0
6 am
7
8
9
10
11 am
12 NOON

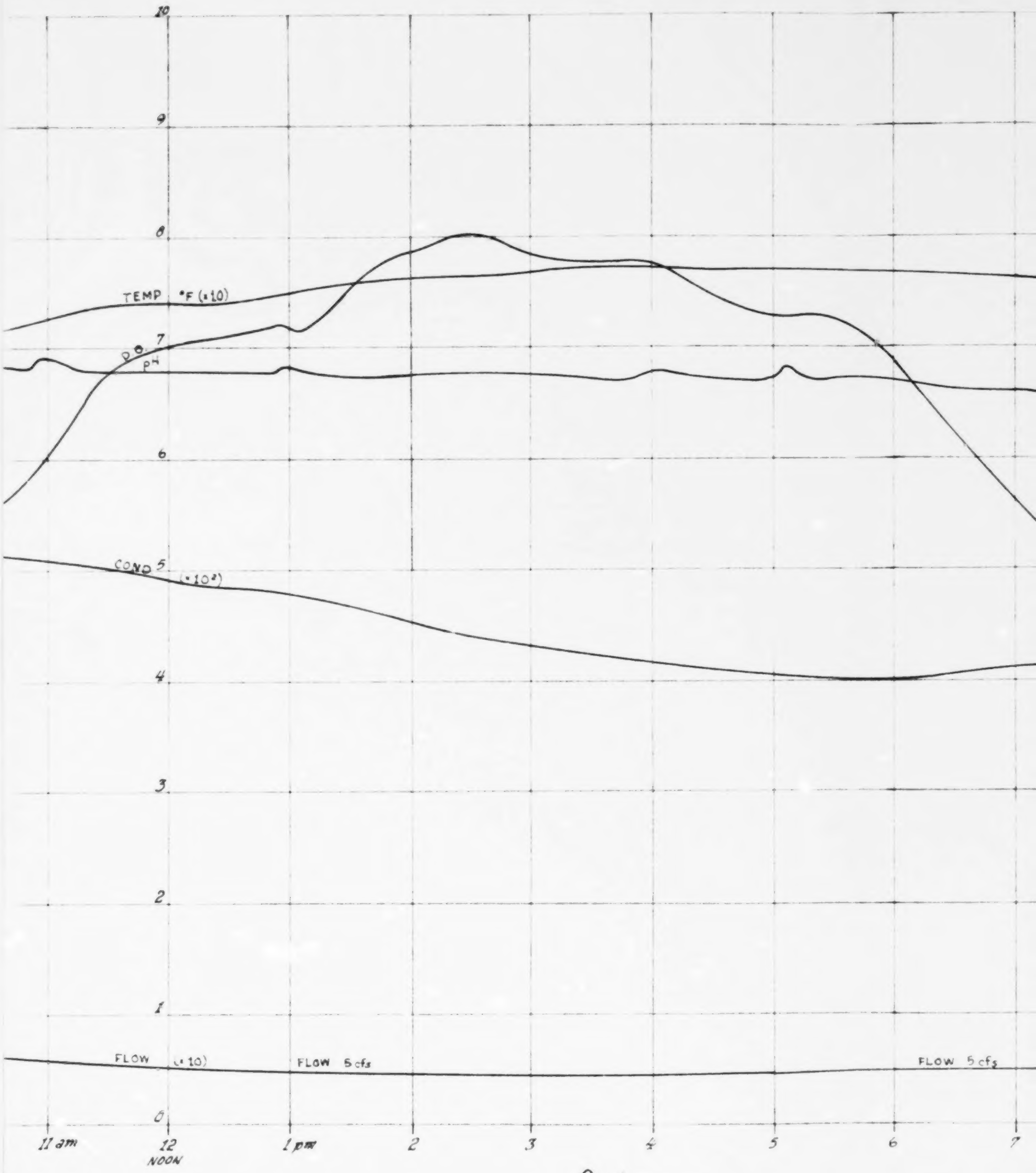


STATION 14

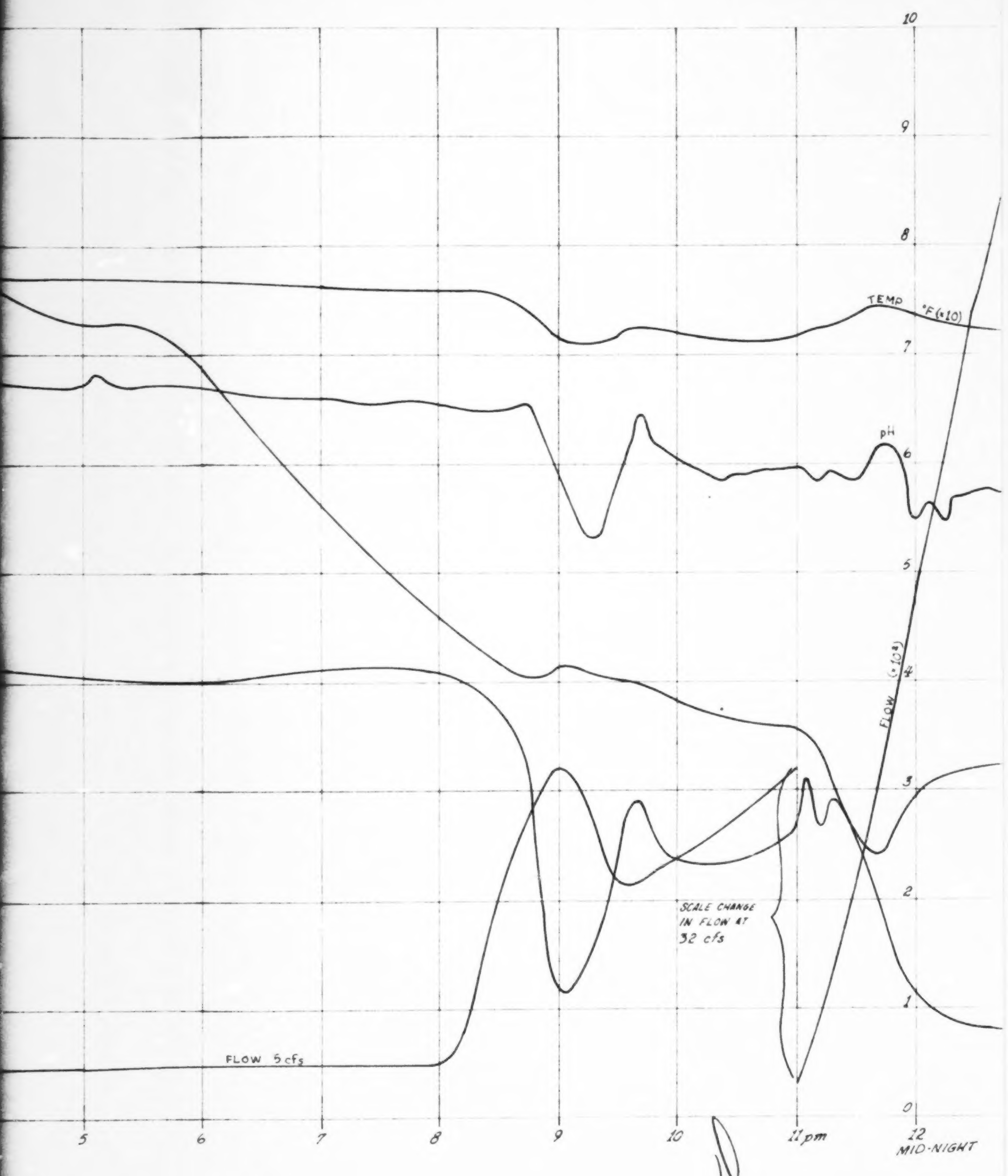
September 15, 16 & 17, 1968

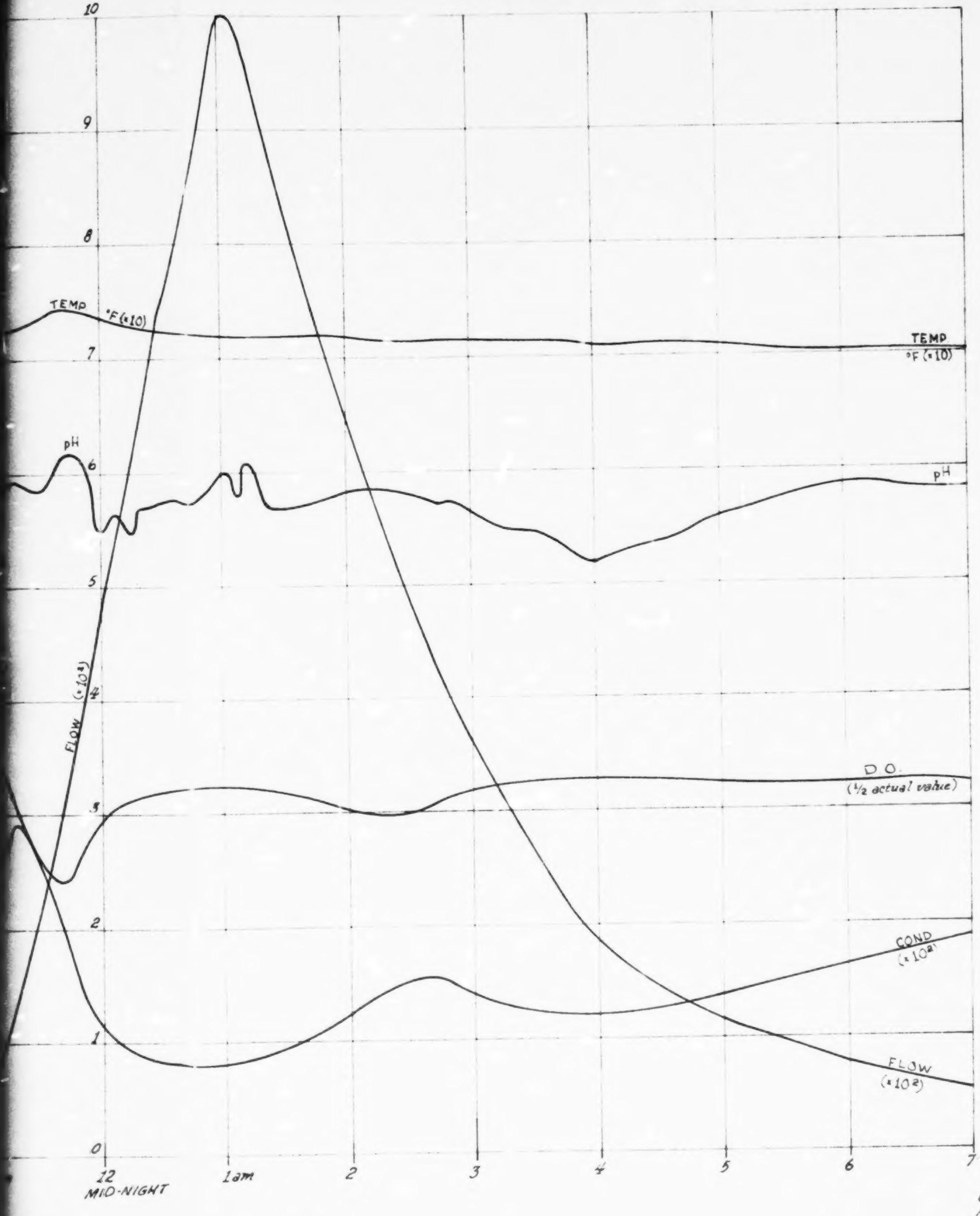
A


16 (17 , 1968
3
4
5
6
7
8
9
10
B

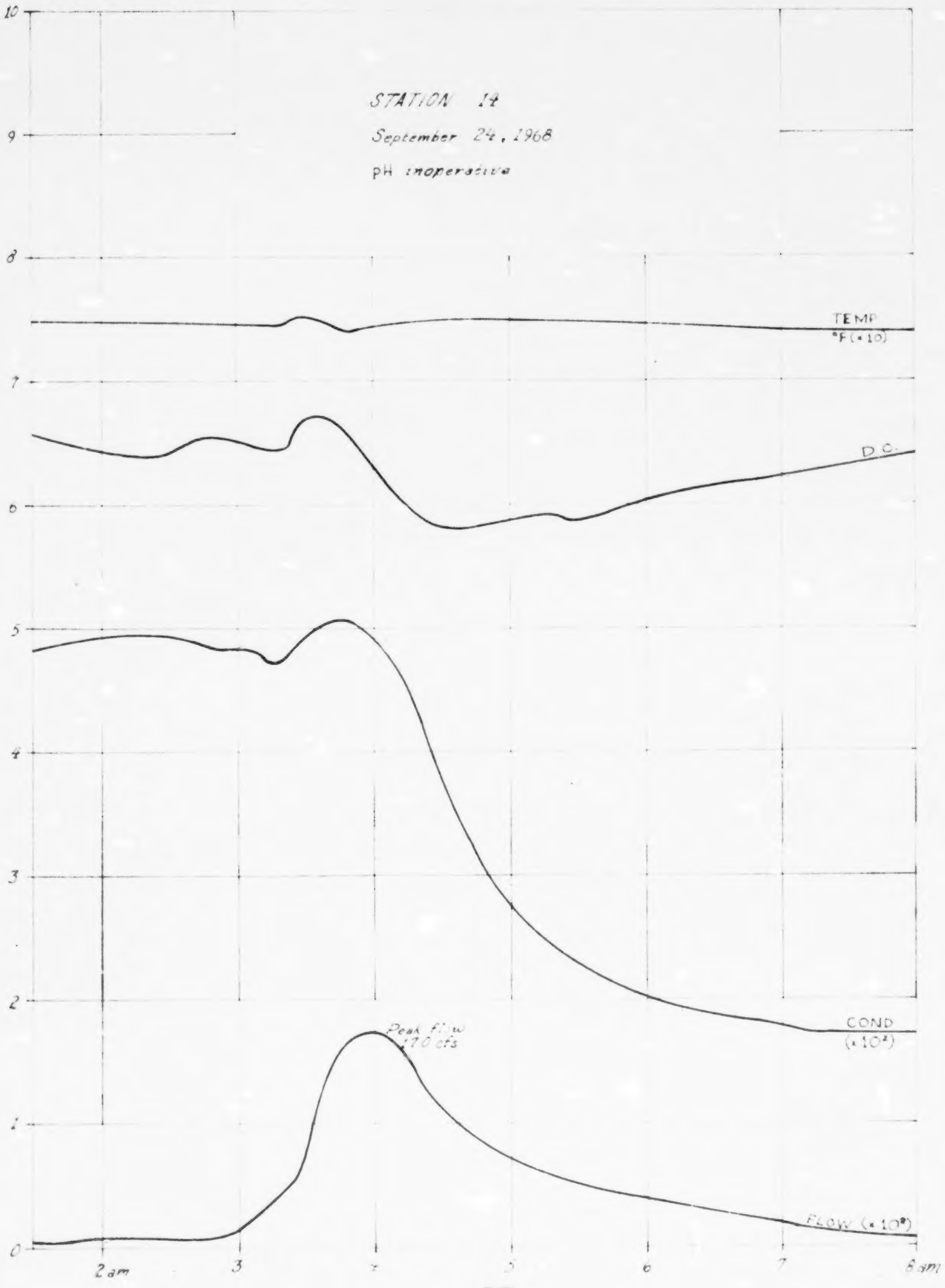

10
9
8
7
6
5
4
3
2
1
0
TEMP °F (×10)
D.O.
pH
COND (×10²)
FLOW (×10)
FLOW 5 cfs
FLOW 5 cfs
11 am
12 NOON
1 pm
2
3
4
5
6
7

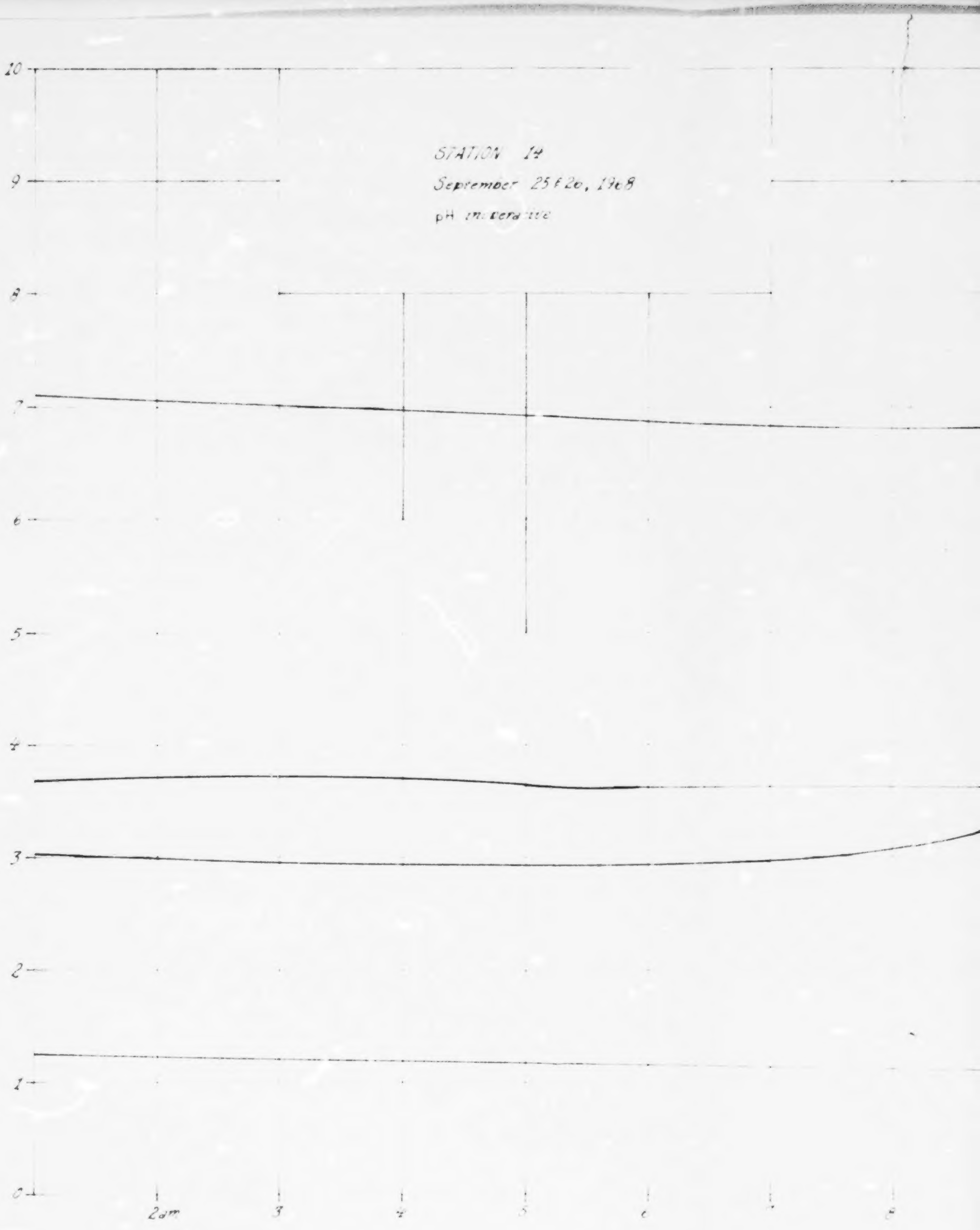
C


10
9
8
TEMP °F(÷10)
7
pH
6
5
FLOW (×10²)
4
3
2
SCALE CHANGE IN FLOW AT 32 cfs
1
FLOW 5 cfs
0
5
6
7
8
9
10
11pm
12 MID-NIGHT


10
9
8
7
6
5
4
3
2
1
0
TEMP °F (×10)
TEMP °F (×10)
pH
pH
FLOW (×10²)
D.O. (½ actual value)
COND (×10²)
FLOW (×10²)
12 MID-NIGHT
1am
2
3
4
5
6
7

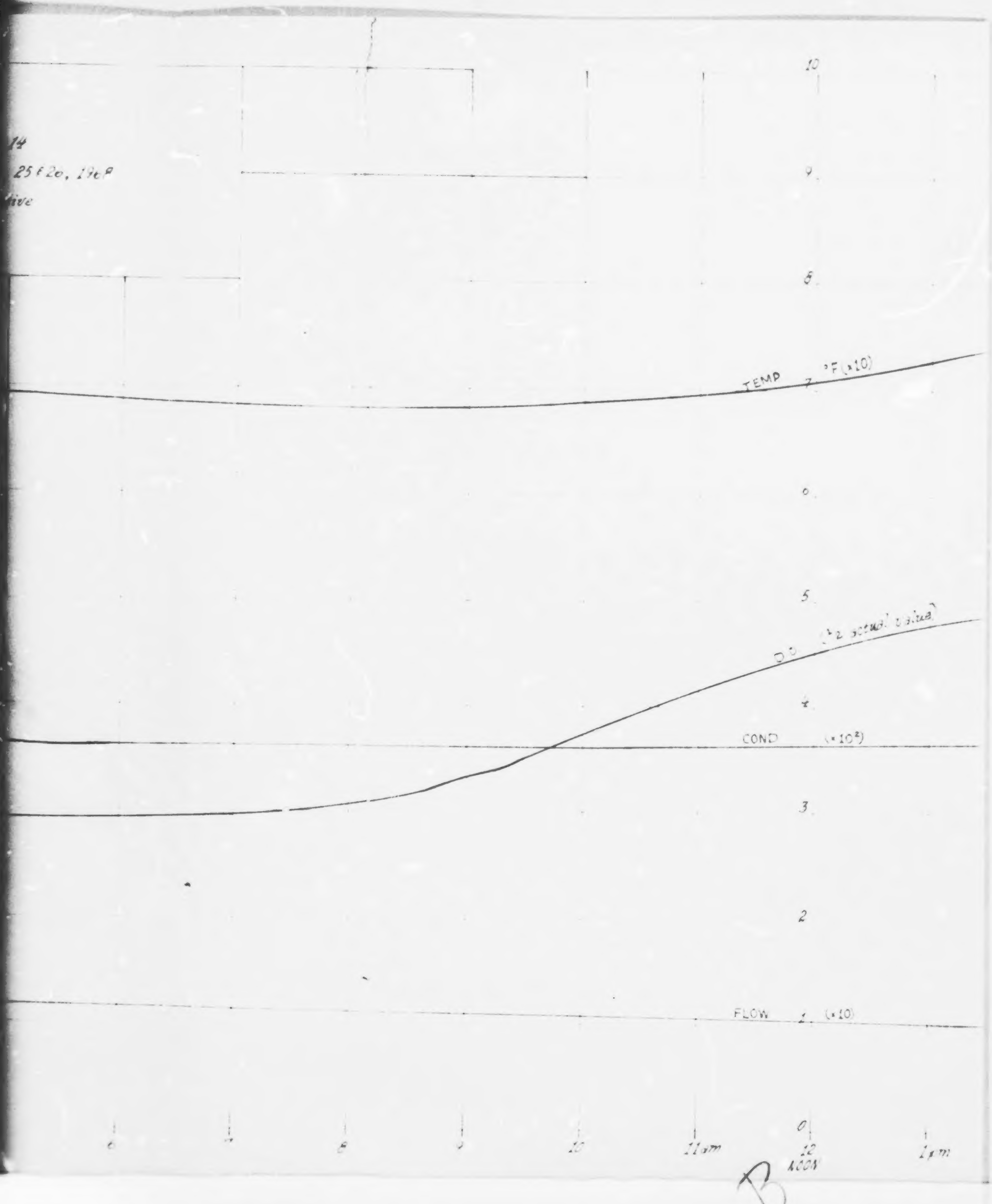
E

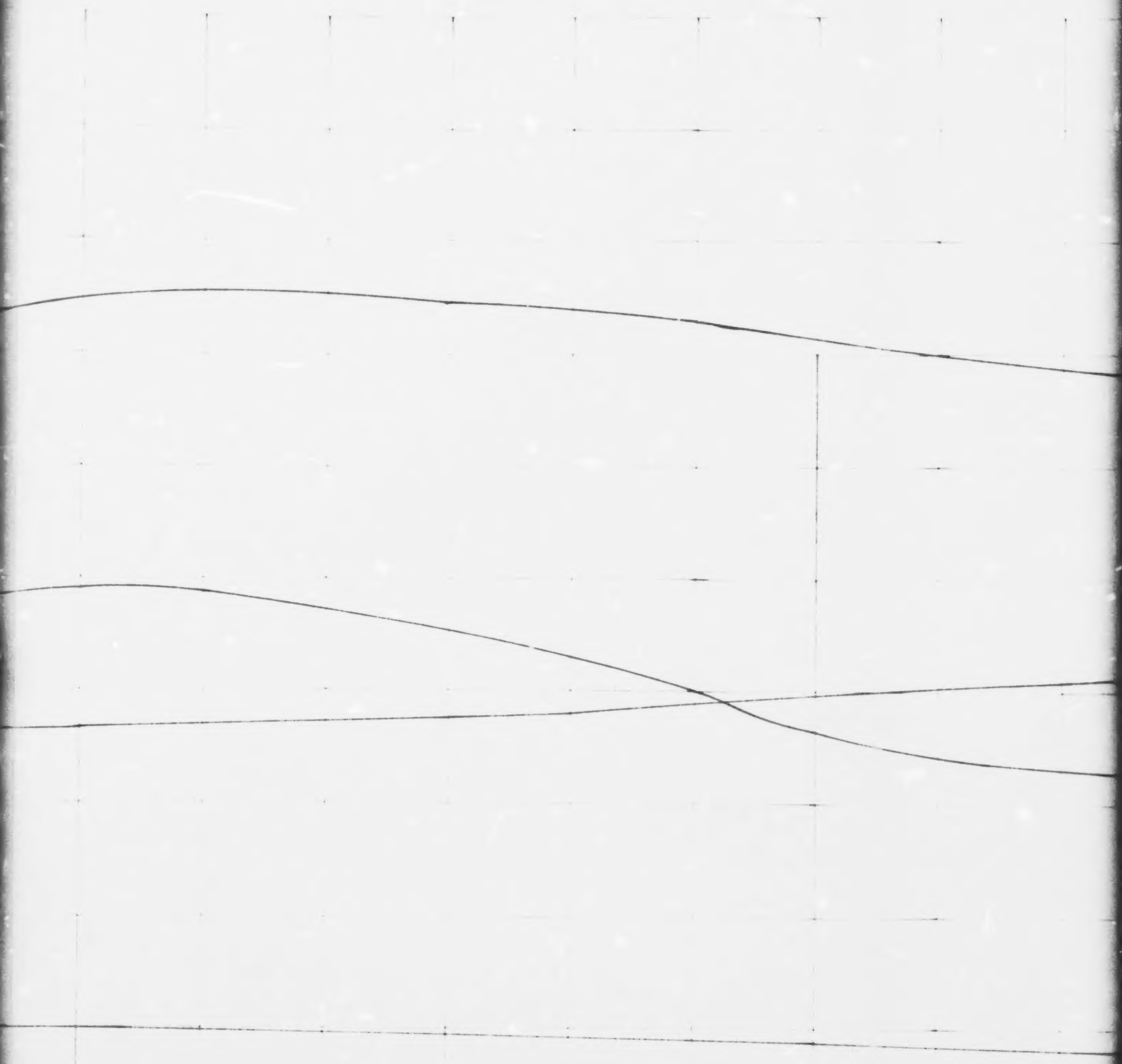

STATION 14
September 24, 1968
pH inoperative
TEMP °F (×10)
D.O.
COND (×10²)
FLOW (×10²)
Peak flow 170 cfs
10
9
8
7
6
5
4
3
2
1
0
2 am
3
4
5
6
7
8 am



STATION 14
September 25 & 26, 1968
pH inoperative

A


14
25 & 20, 196
tive
10
9
8
TEMP
7
°F (×10)
6
5
D.O.
(½ actual value)
4
COND
(×10²)
3
2
FLOW
1
(×10)
0
6
7
8
9
10
11am
12
NOON
1pm
B


2
3
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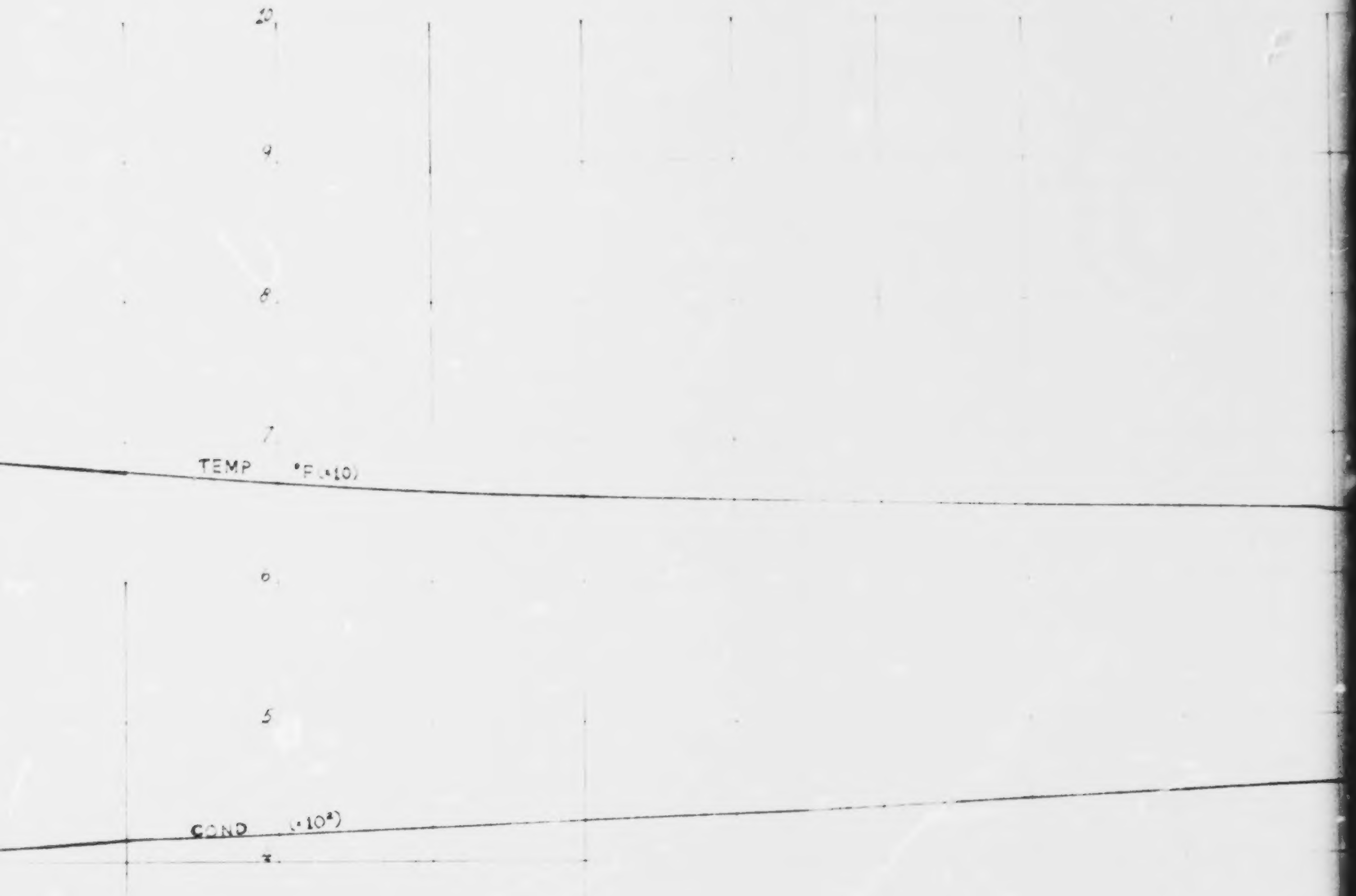
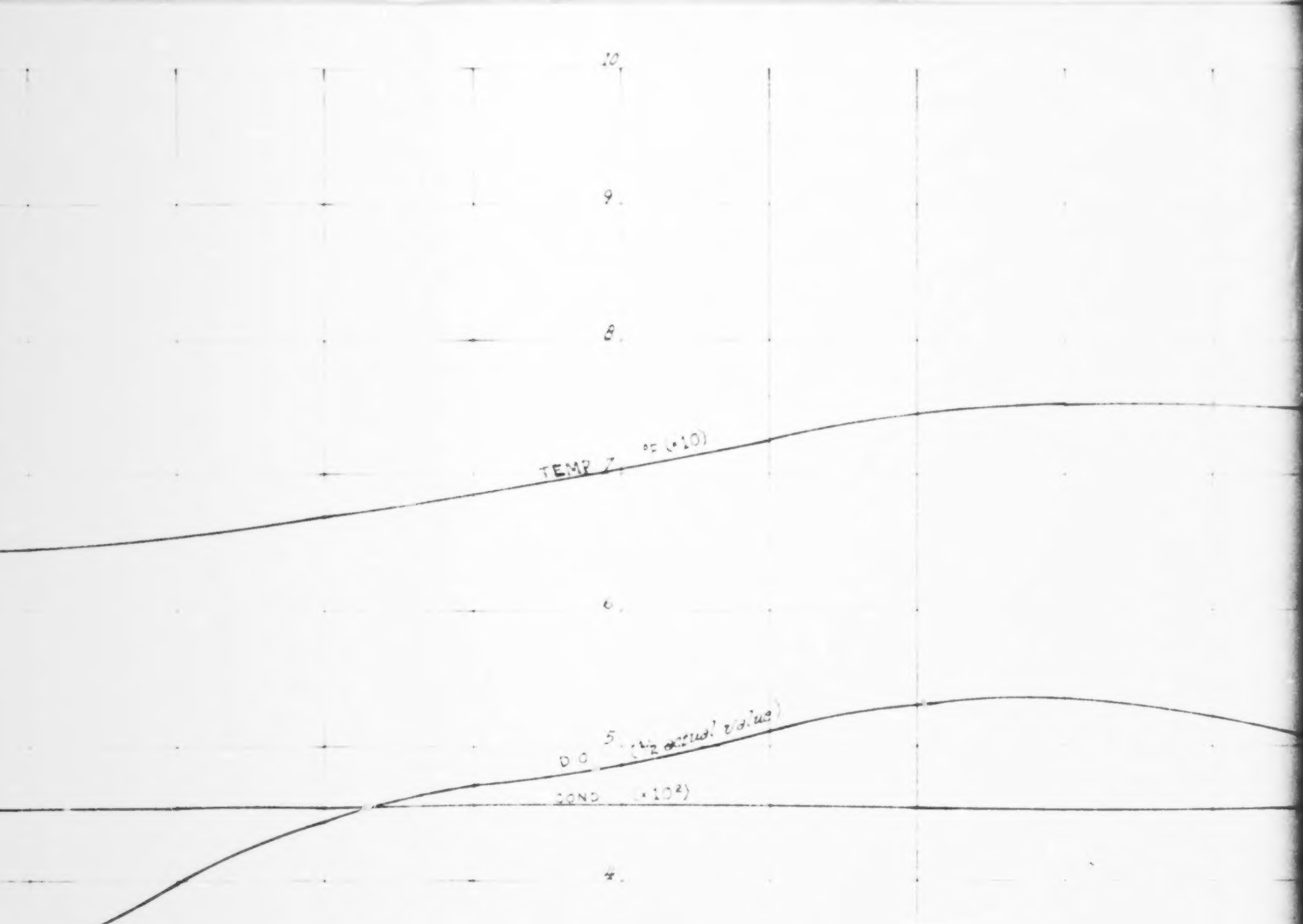
10

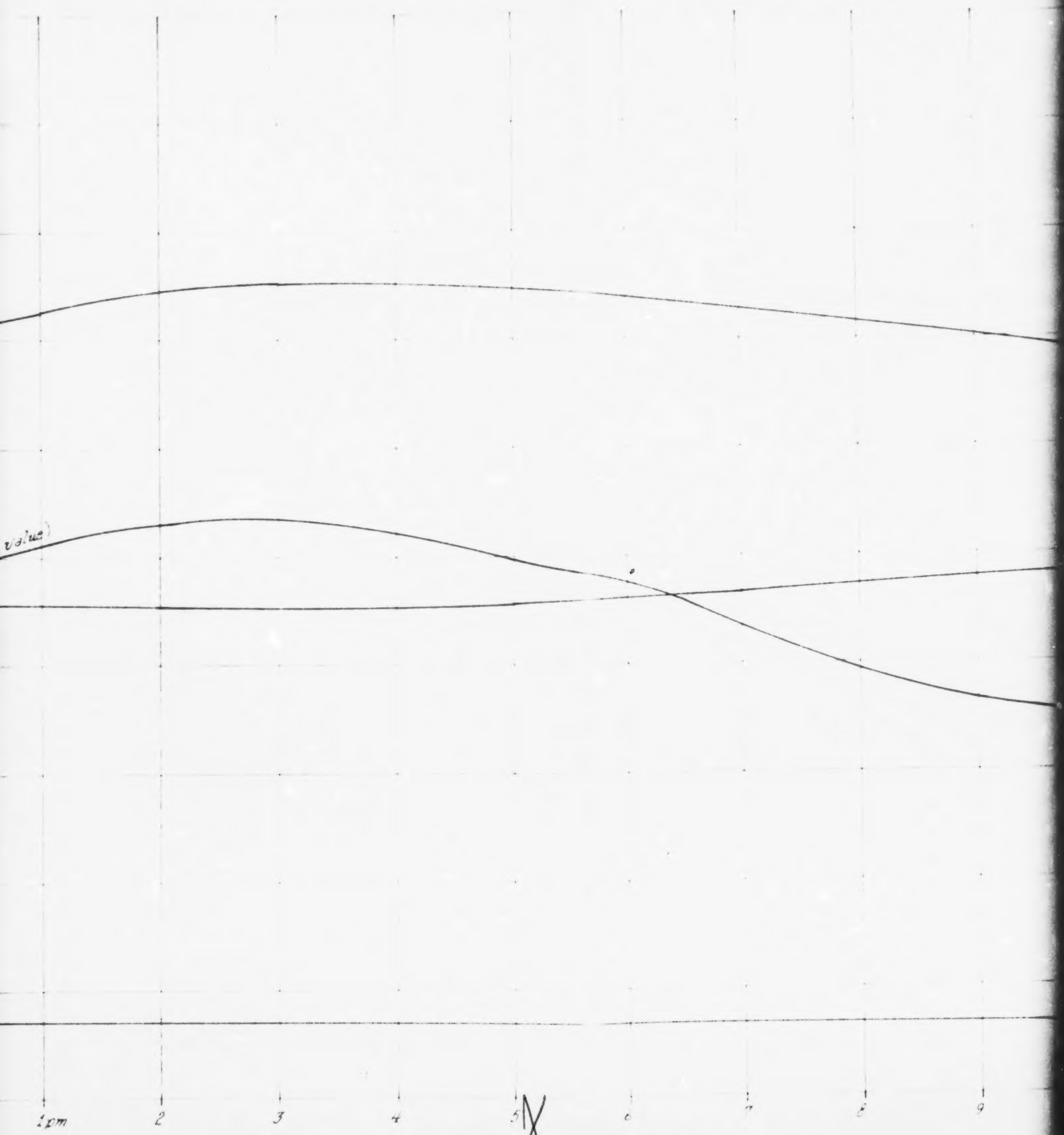


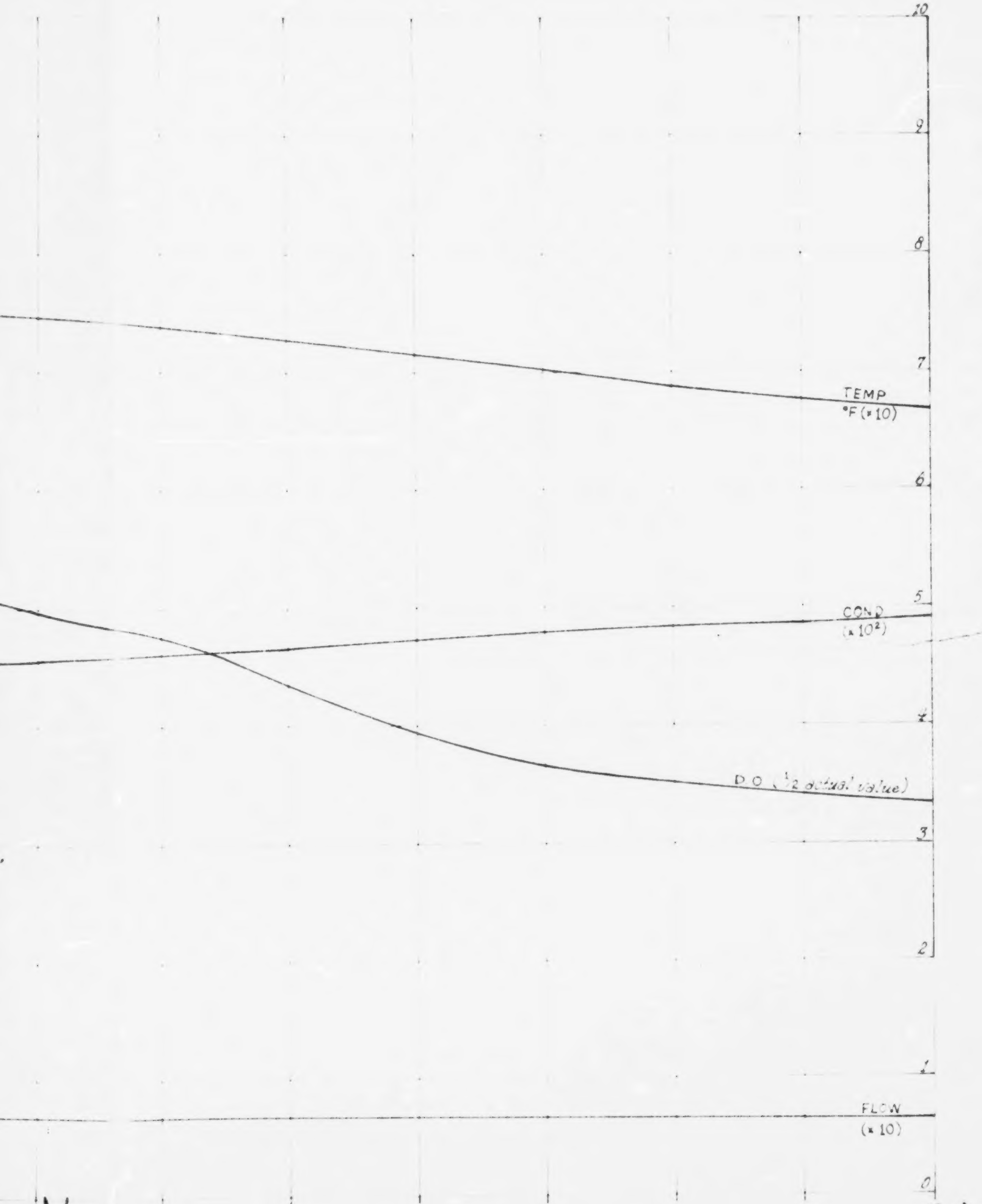
10
9
8
7
TEMP °F (×10)
6
5
COND (×10²)
4
D O (½ actual value)
3
2
1
FLOW (×10)
0
11pm
12 MID-NIGHT
1am
2
3
4
5
6

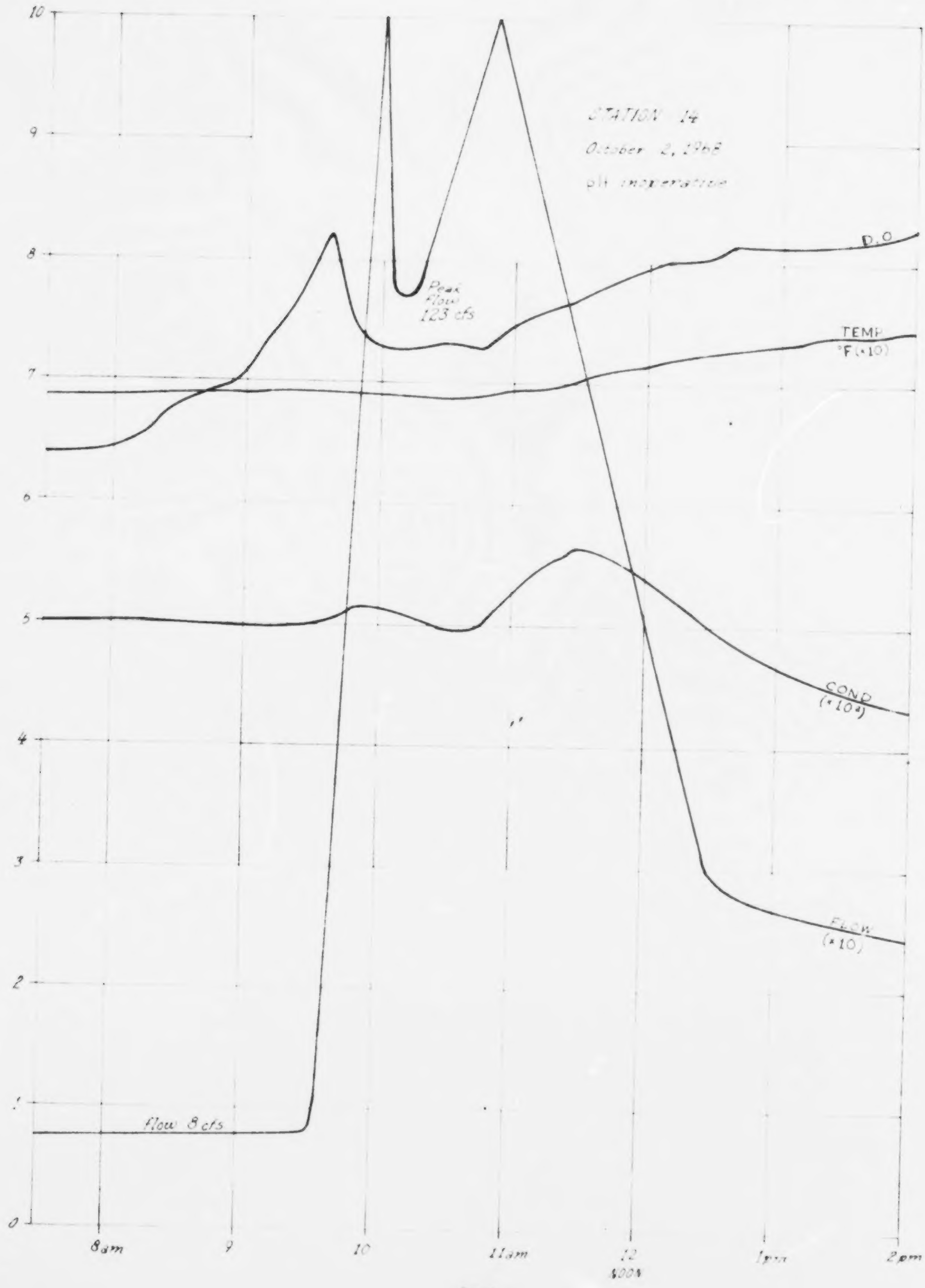
D



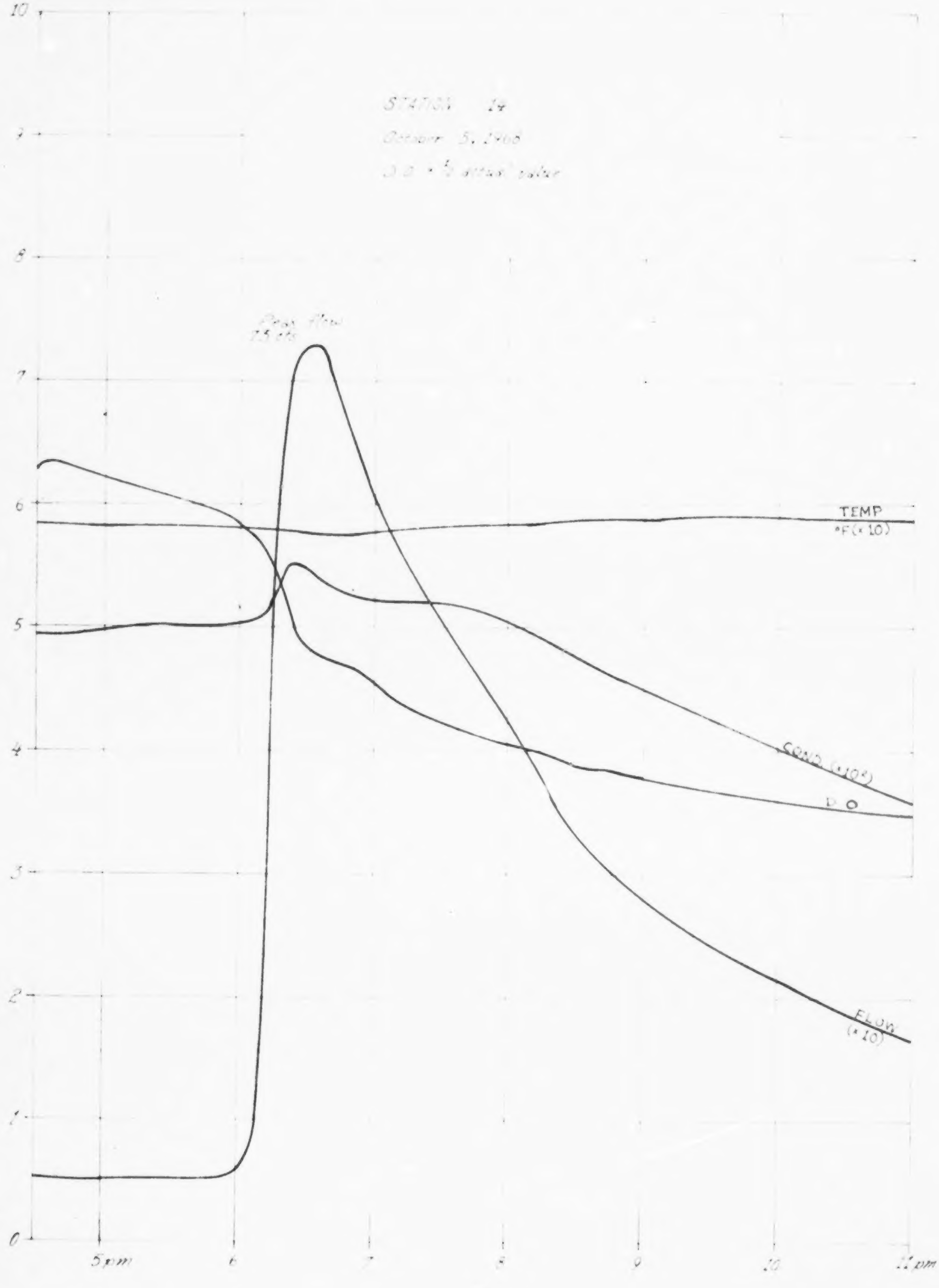
10
9
8
TEMP 7 °F (×10)
6
D.O. 5 (½ actual value)
COND (×10²)
4
3
2
1
FLOW (×10)
0
8
9
10
11am
12 NOON
1pm
2
3
4

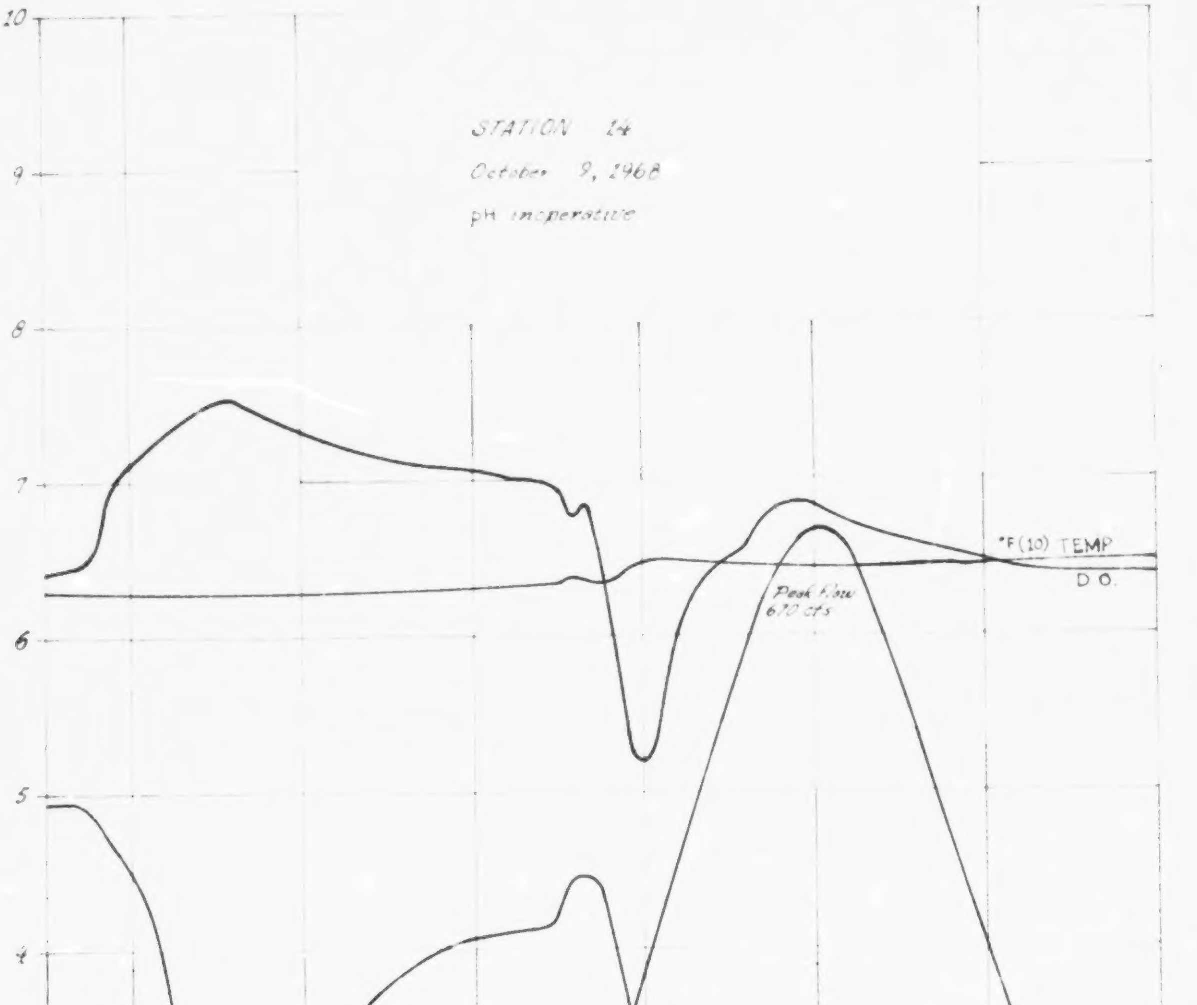

value)
1pm
2
3
4
5
6
7
8
9

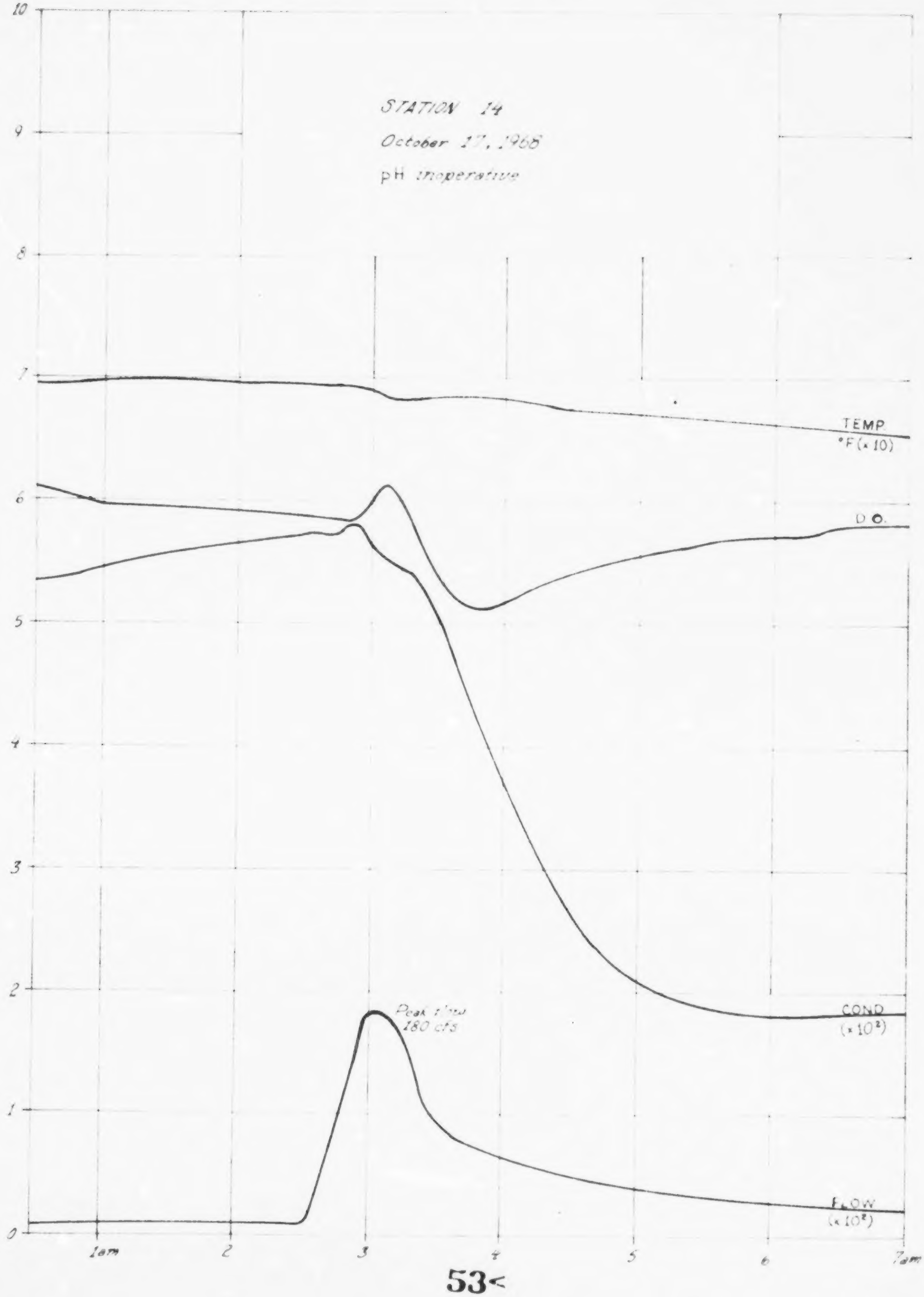

10
9
8
7
TEMP
°F (×10)
6
5
COND
(×10²)
4
D.O (½ actual value)
3
2
1
FLOW
(×10)
0
5
6
7
8
9
10
11
12
M.D-N16



STATION 14
October 2, 1968
pH inoperative


STATION 14
October 5, 1966
D.O. × ½ actual value
Peak flow
73 cfs
TEMP
°F (×10)
COND. (×10²)
D.O.
FLOW
(×10)
10
9
8
7
6
5
4
3
2
1
0
5 pm
6
7
8
9
10
11 pm


STATION 14
October 9, 1968
pH inoperative
°F (10) TEMP
D.O.
Peak Flow 670 cfs
FLOW (×10²)
COND (×10²)
10
9
8
7
6
5
4
3
2
1
0
6 am
7
8
9
10
11 am
12 NOON

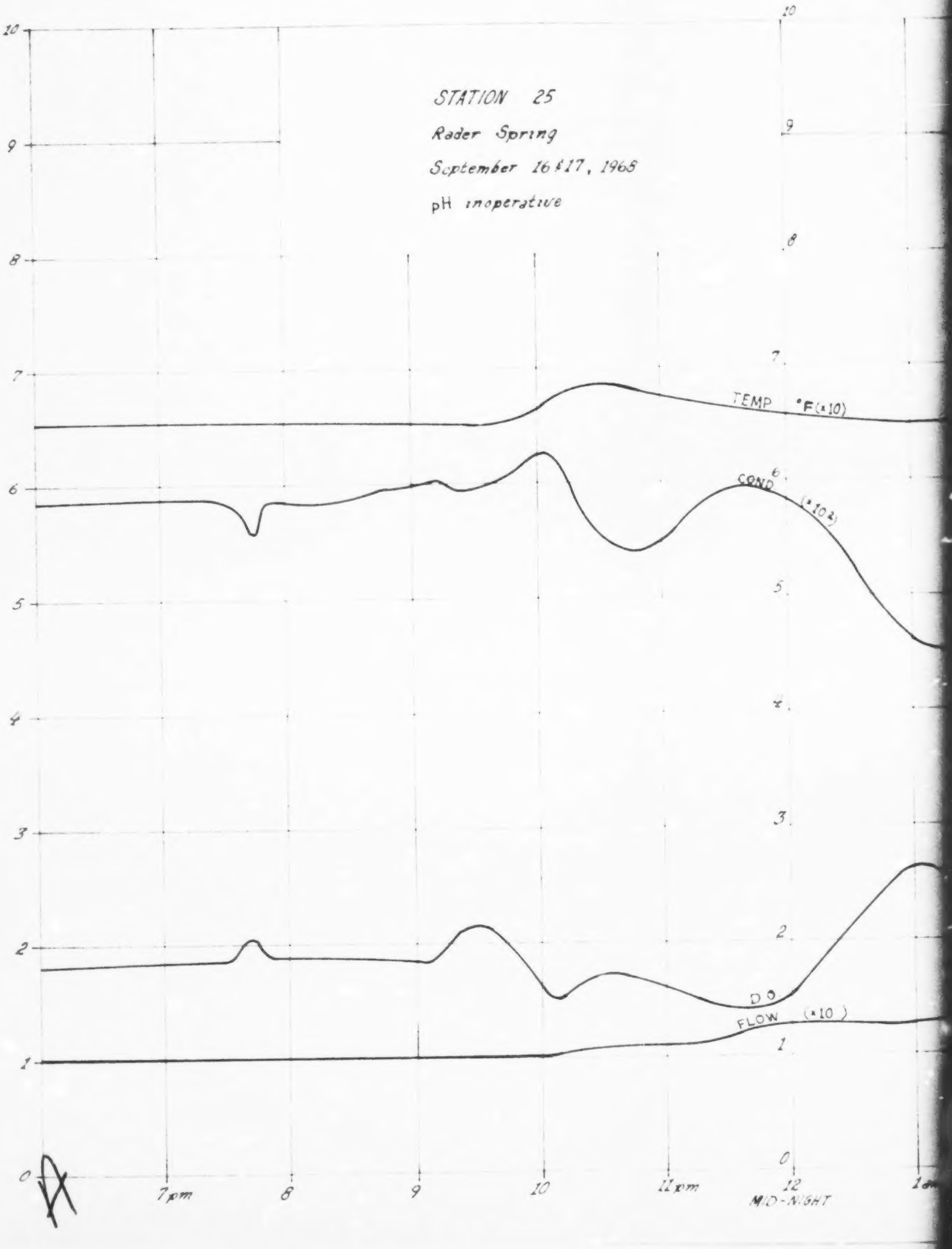


STATION 14

October 17, 1966

pH inoperative

Peak flow 180 cfs

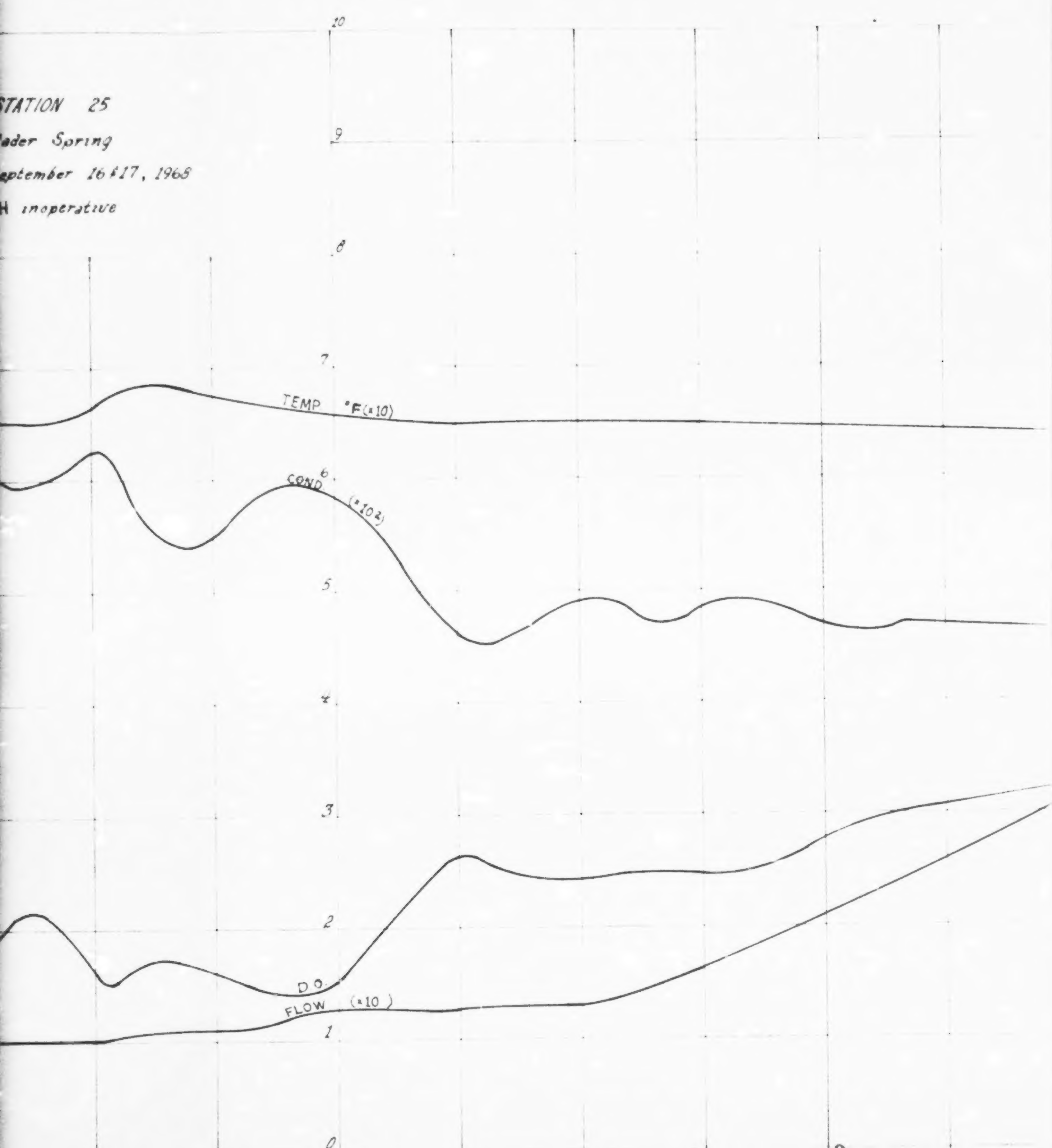


STATION 25

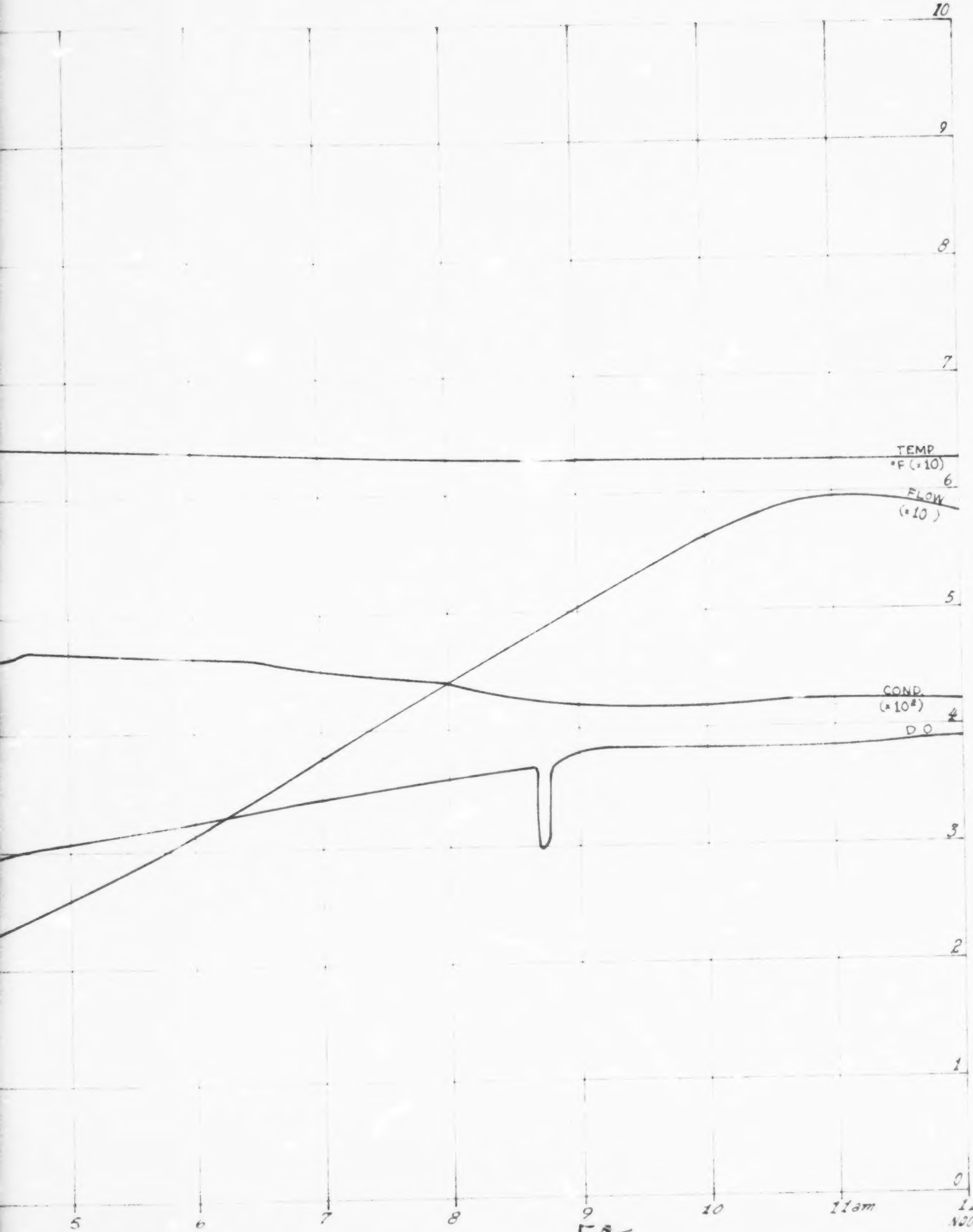
Rader Spring

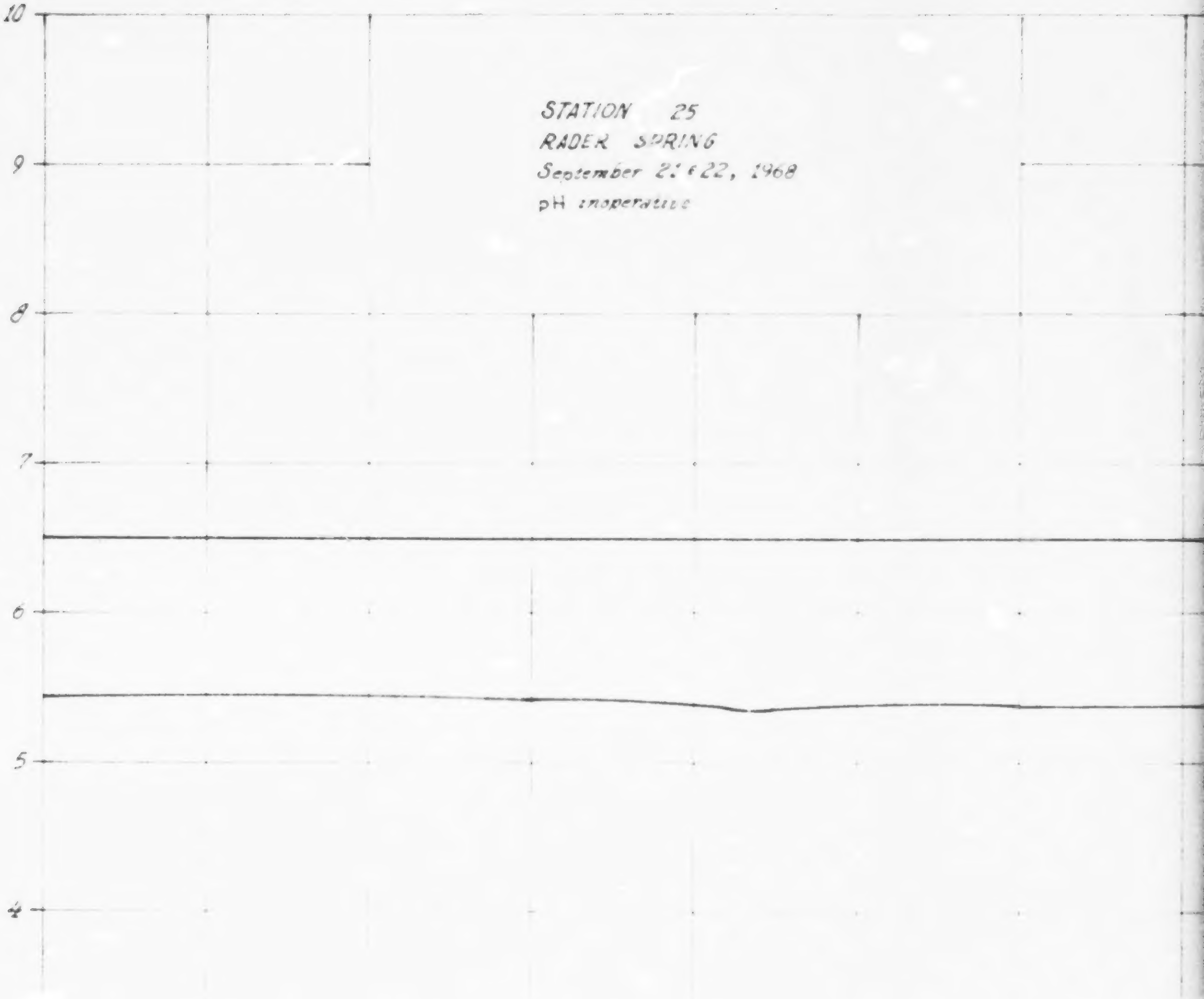
September 16 & 17, 1968

pH inoperative

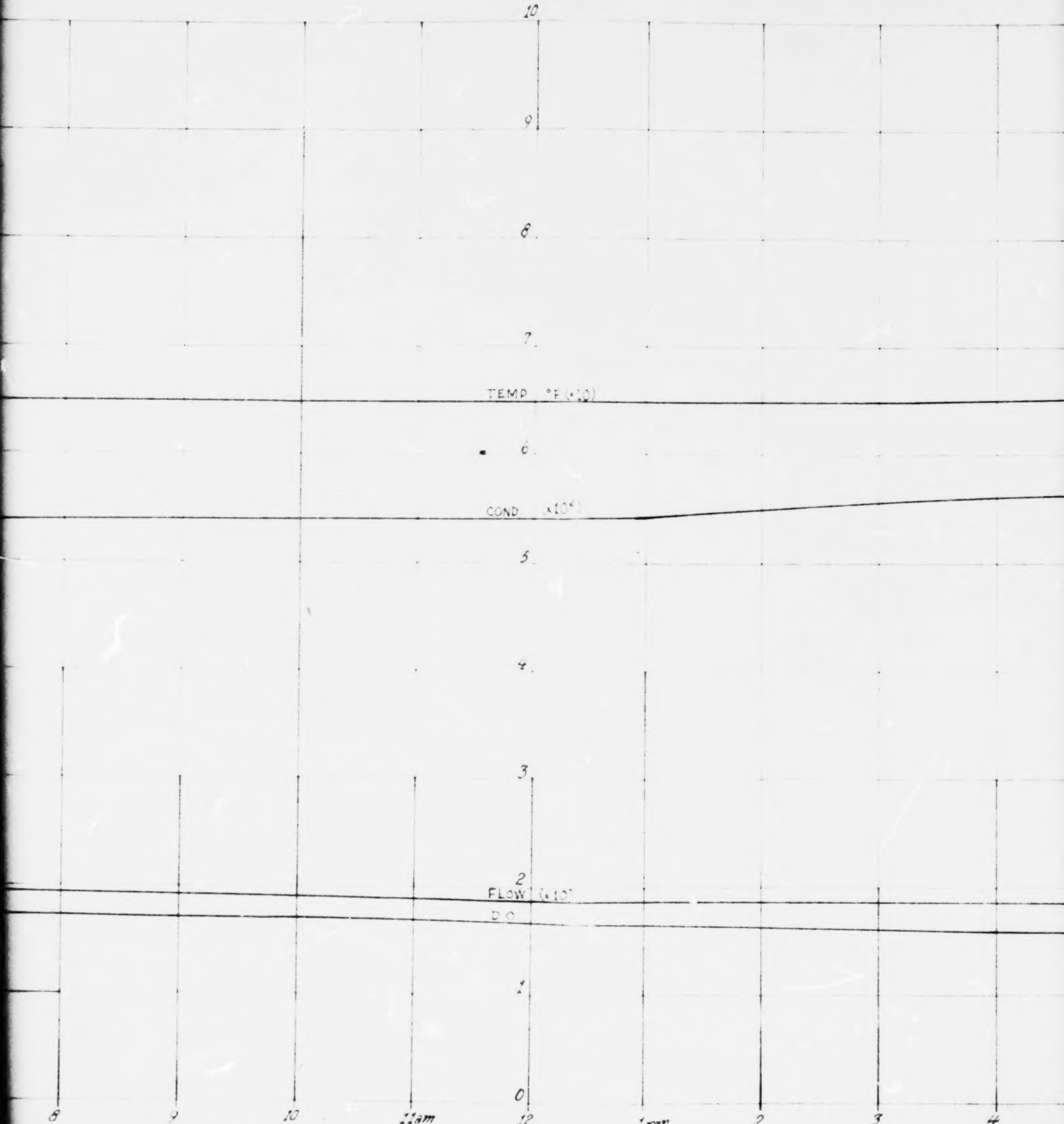


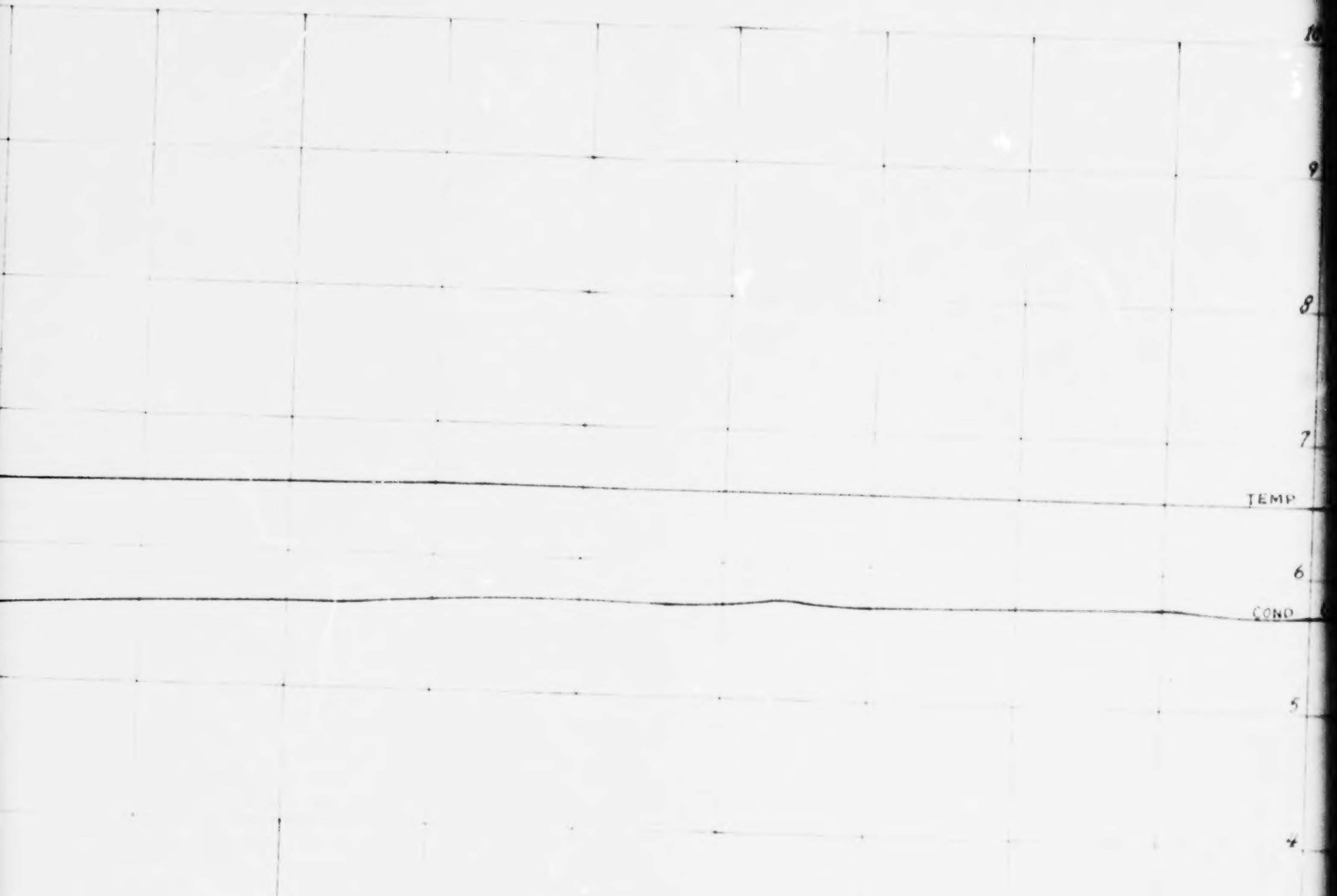
STATION 25
ader Spring
eptember 16&17, 1968
H inoperative


10
9
8
7
TEMP
°F (×10)
6
FLOW
(×10)
5
COND.
(×10²)
4
D O
3
2
1
0
5
6
7
8
9
10
11am
12
NOON



STATION 25
RADER SPRING
September 21 & 22, 1968
pH inoperative


10
9
8
7
TEMP °F (×10)
6
COND (×10²)
5
4
3
2
FLOW (×10)
D.O.
1
0
8
9
10
11am
12 NOON
1pm
2
3
4



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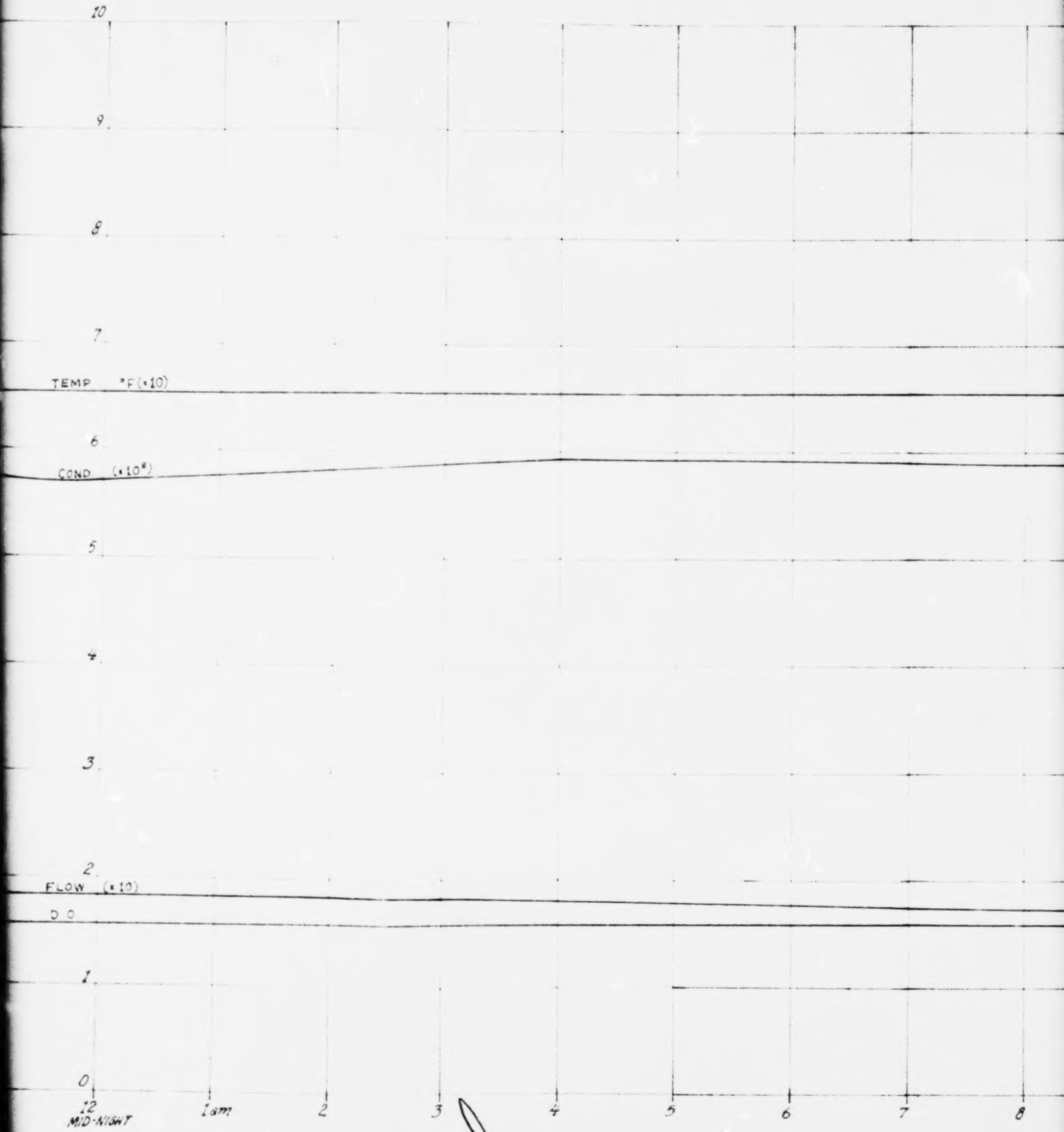
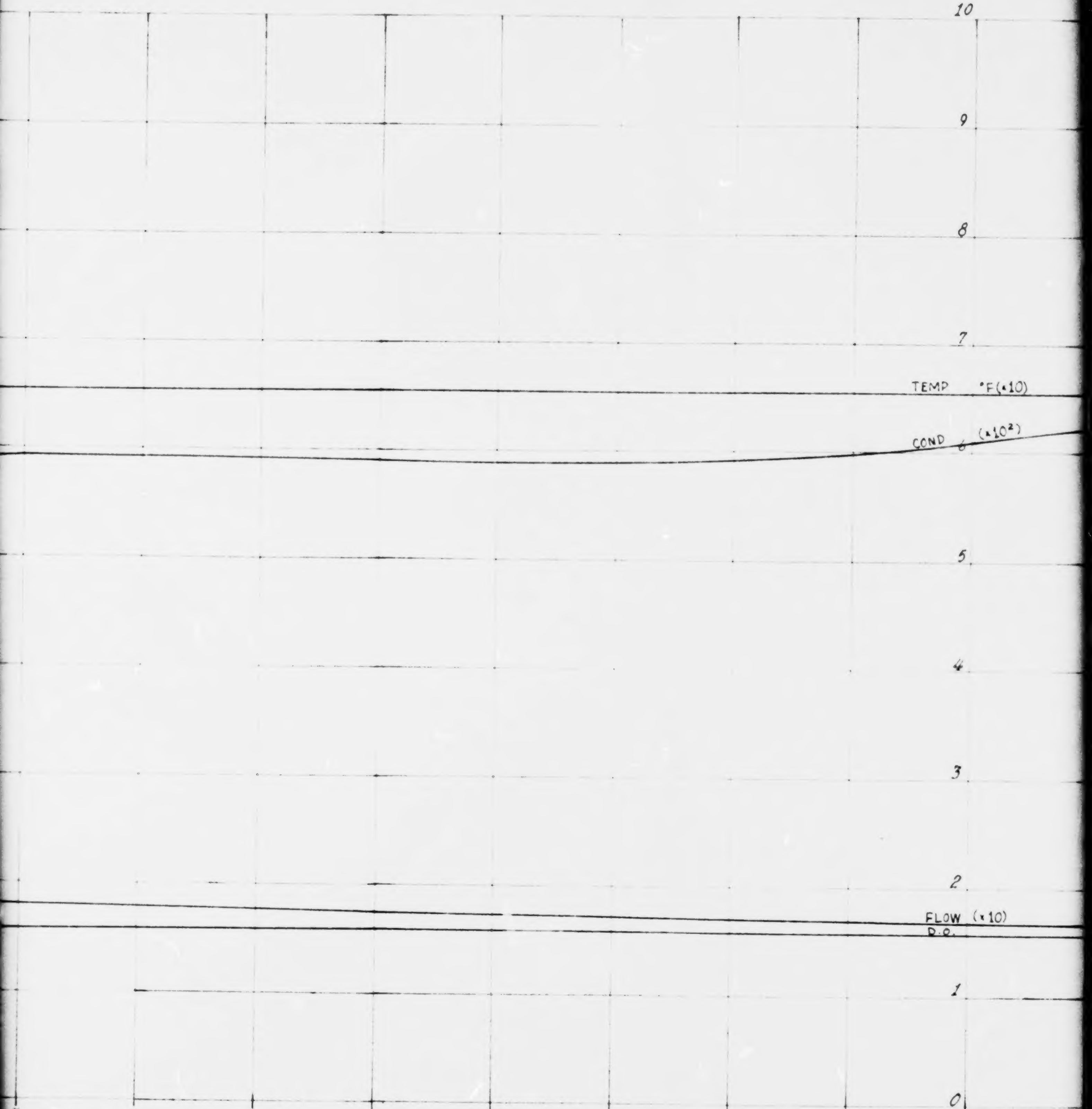
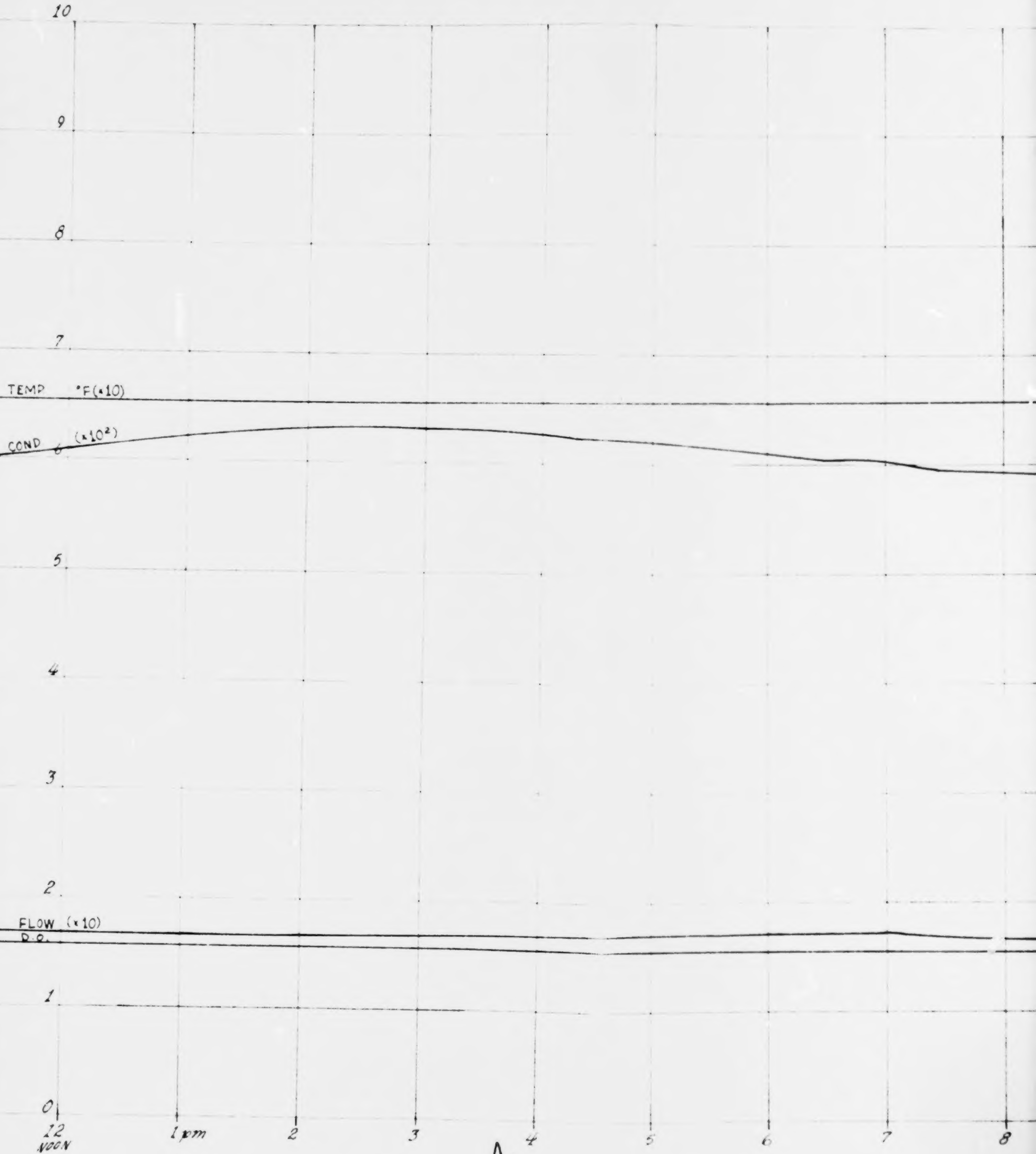
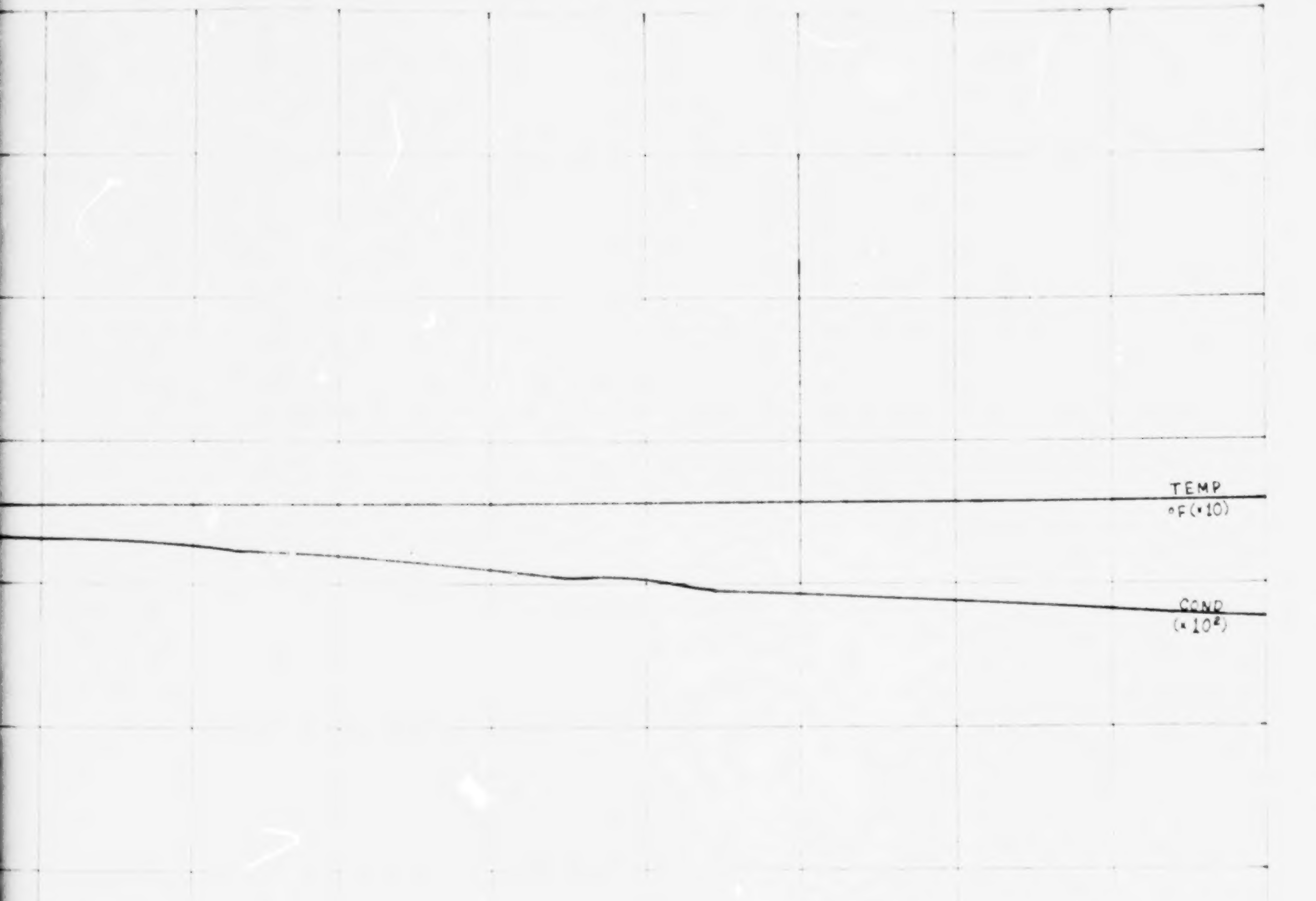
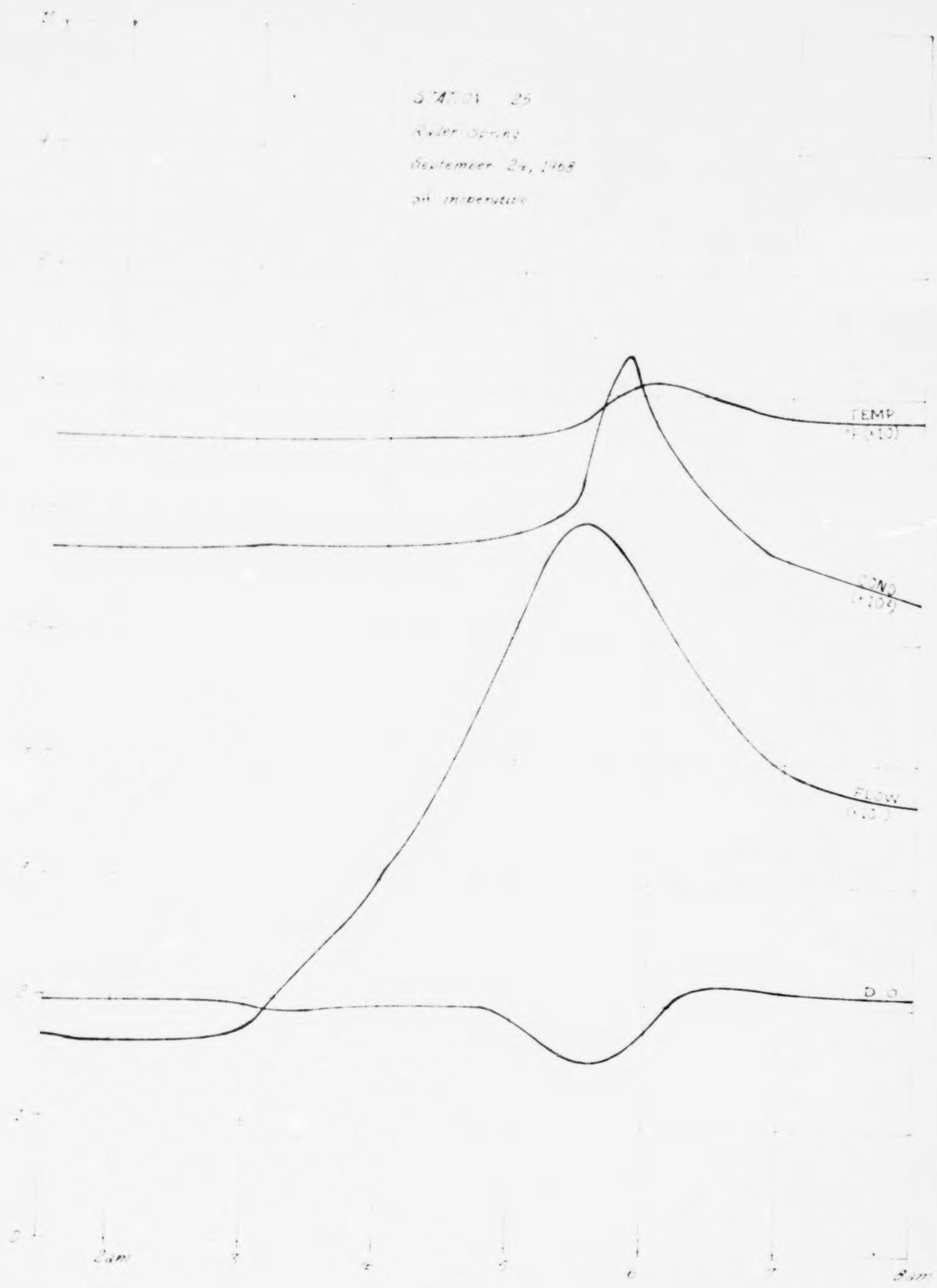

10
9
8
7
TEMP °F (×10)
6
COND (×10²)
5
4
3
2
FLOW (×10)
D O
1
0
12 MID-NIGHT
1am
2
3
4
5
6
7
8

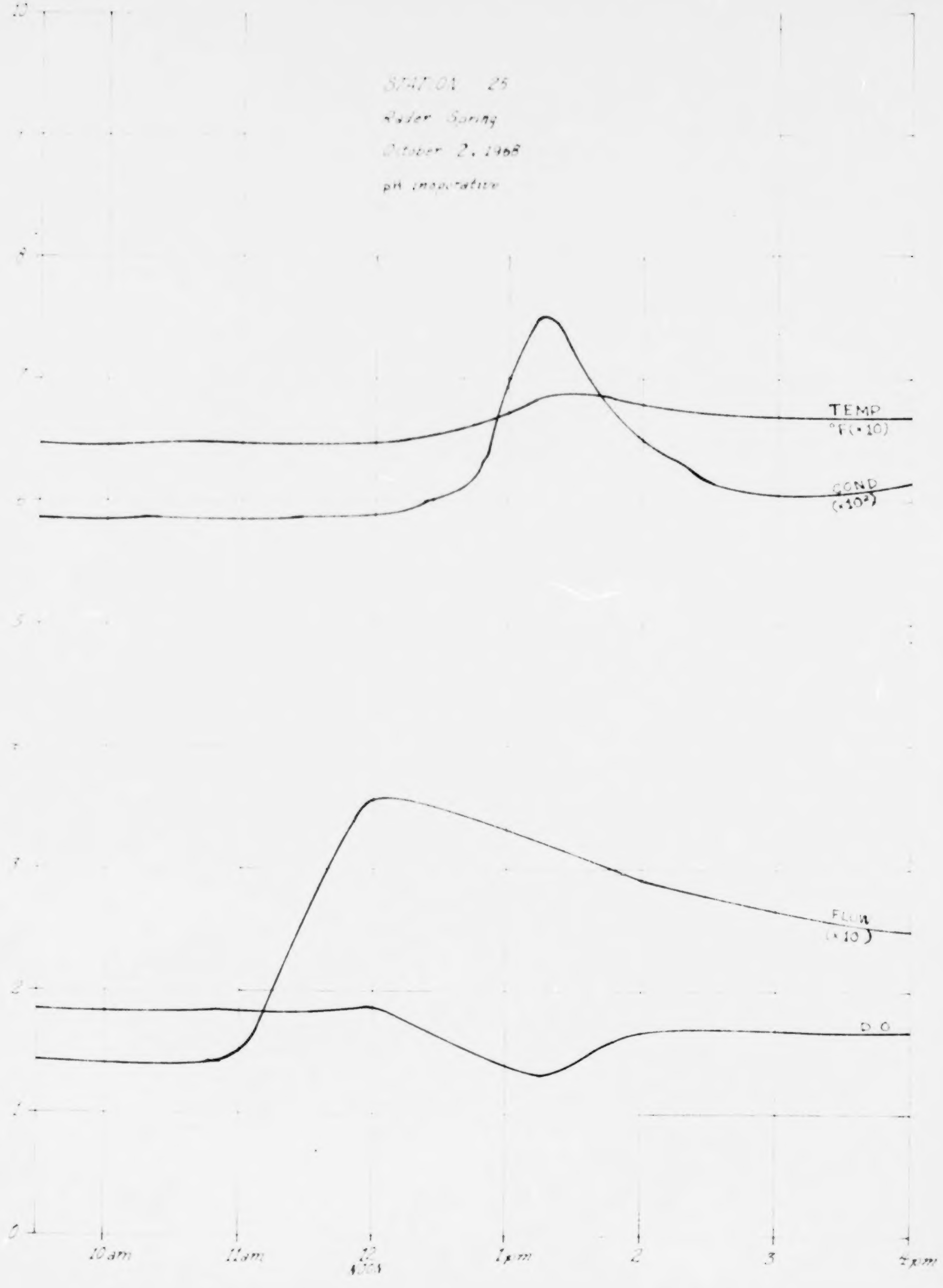

10
9
8
7
TEMP °F(×10)
COND (×10²)
6
5
4
3
2
FLOW (×10)
D.O.
1
0
4
5
6
7
8
9
10
11 am
12 NOON

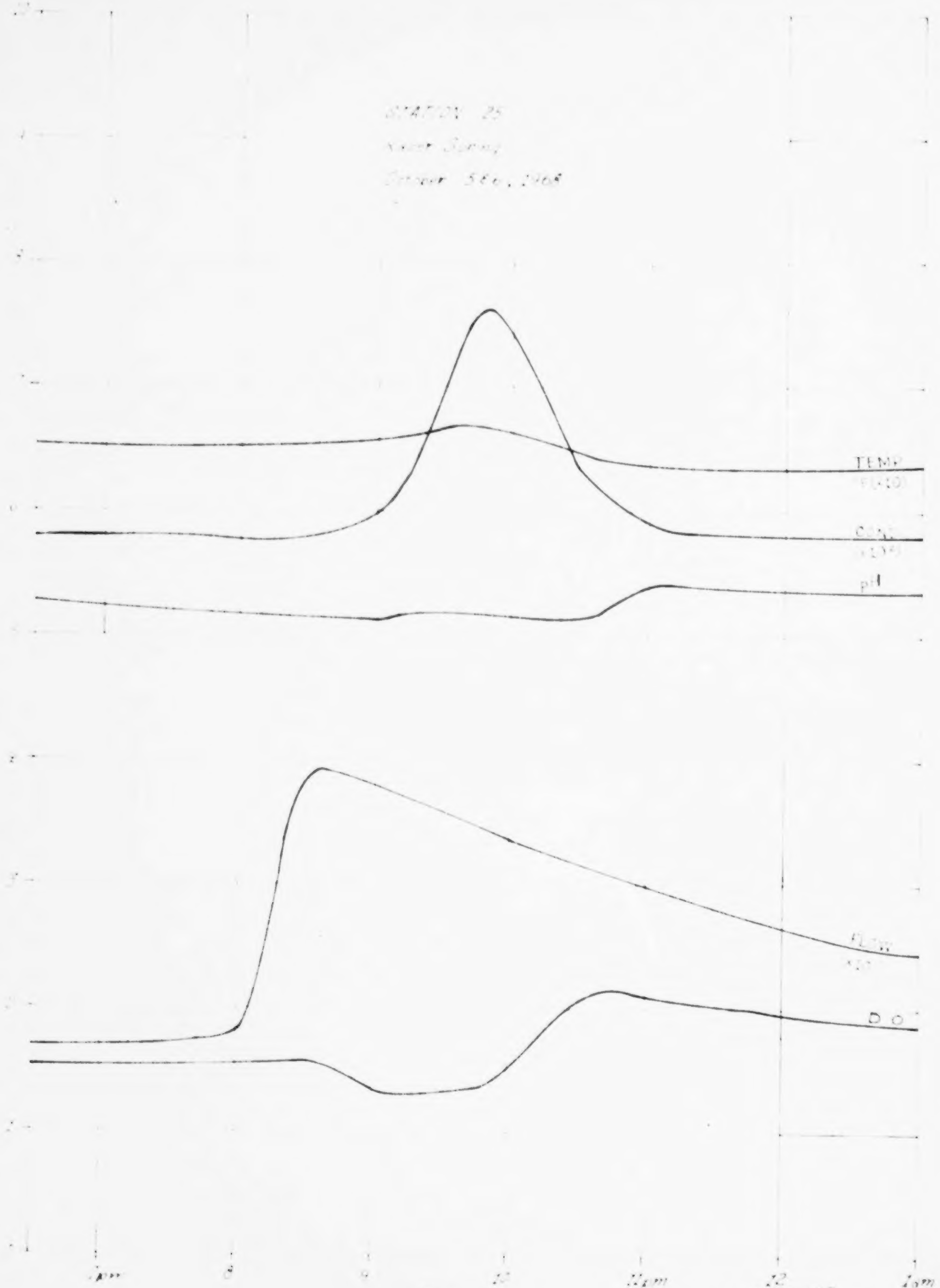


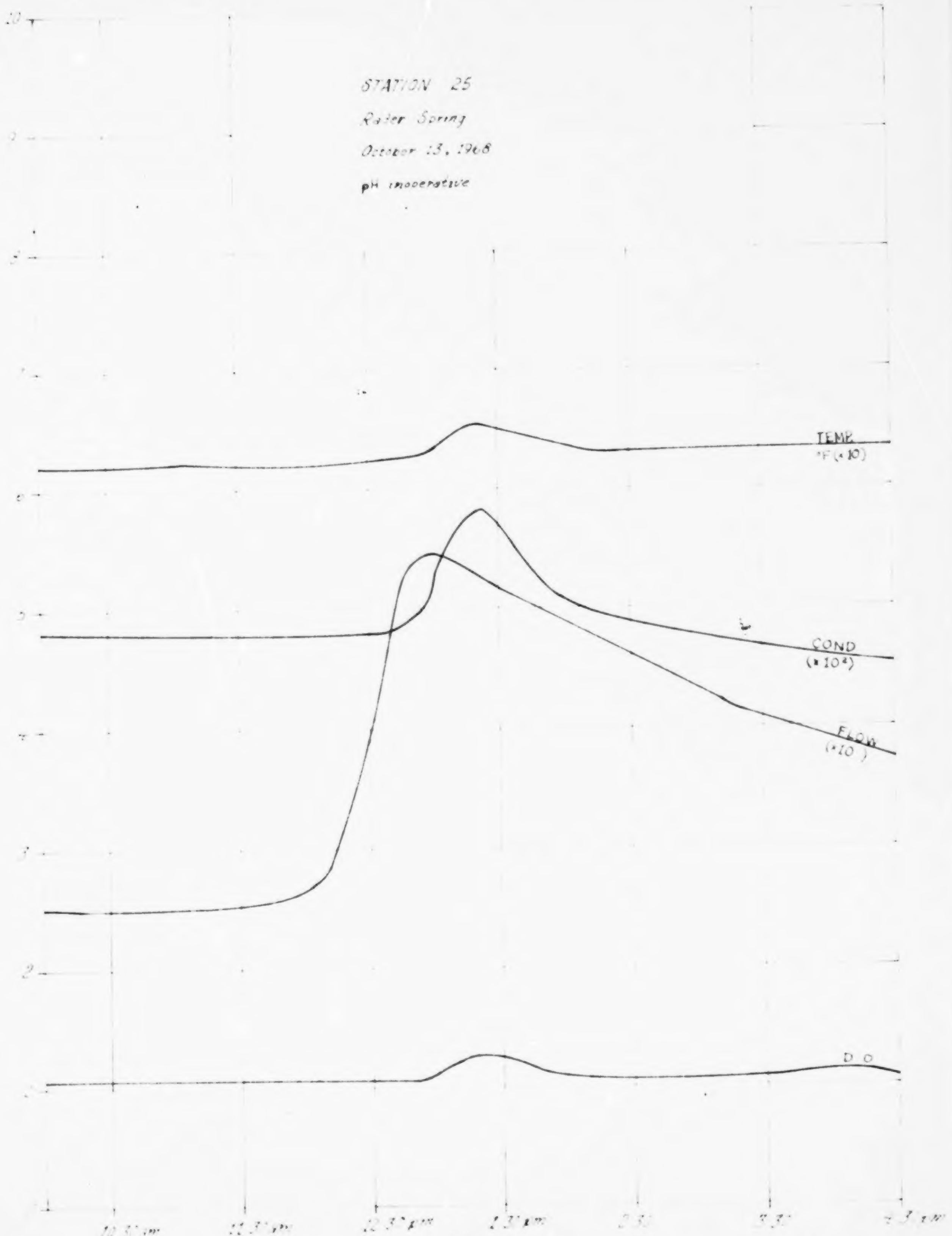
10
9
8
7
TEMP °F(×10)
COND (×10²)
6
5
4
3
2
FLOW (×10)
D.O.
1
0
12 NOON
1 pm
2
3
4
5
6
7
8


TEMP
°F (×10)
COND
(×10²)
FLOW (×10)
0.0
3
4
5
6
7
8
9
10
11 pm


STATION 25
Ruder Spring
September 24, 1968
pH inoperative
TEMP
°F (×10)
COND
(×10³)
FLOW
(×20)
D.O.
0
1
2
2am
3
4
5
6
7
8am


STATION 25
Rader Spring
October 2, 1968
pH inoperative
10
8
7
6
5
3
2
1
0
TEMP
°F(×10)
COND
(×10²)
FLOW
(×10)
D.O.
10am
11am
12
NOON
1pm
2
3
4pm


STATION 25
Spring
October 5th, 1968
TEMP
°F(-10)
COND
pH
FLOW
D.O.
7pm
8
9
10
11pm
12
MIDNIGHT
1am


STATION 25
Rader Spring
October 13, 1968
pH inoperative
10
9
8
7
6
5
4
3
2
1
TEMP
°F (×10)
COND
(×10²)
FLOW
(×10)
D O
10:30 am
11:30 am
12:30 pm
1:30 pm
2:30
3:30
4:30 pm

APPENDIX B

BENTHIC STUDY

JAMES RIVER-WILSON CREEK STUDY
Springfield, Missouri

APPENDIX B

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SUMMARY

A survey of the bottom dwelling invertebrates in the Wilson Creek tributaries, Wilson Creek and James River near Springfield, Missouri, was conducted in March and September of 1968. The purpose of the survey was to characterize the water quality as reflected by the benthic invertebrates. Benthic invertebrate collections reflected poor or degraded conditions in North Wilson Creek, Jordan Creek, Fassnight Creek, and Wilson Creek above the Springfield Southwest Sewage Treatment Plant located on Wilson Creek. Below the sewage treatment plant, benthic invertebrate collections reflected grossly polluted conditions in Wilson Creek for a distance of 6.7 river miles. Terrell Creek enters the pollution laden water of Wilson Creek 6.7 miles below the sewage treatment plant, resulting in water of somewhat improved, but still degraded, quality for a distance of 1.38 river miles, or to the mouth of Wilson Creek. James River, above the confluence of the James River and Wilson Creek, is of good water quality as illustrated by the benthic invertebrate collections. Benthic invertebrate collections from James River below the confluence of James River and Wilson Creek for a distance of 5.5 river miles indicated mild degradation or enrichment. Relative numbers of sensitive forms decreased, and tolerant forms increased for this same area. James River recovery had occurred 39.5 miles below the mouth of Wilson Creek as reflected by the benthic invertebrates collected.

CONCLUSIONS

1. Degradation of water quality in varying degrees is occurring at all stations above the sewage treatment plant on Wilson Creek; North Wilson Creek is particularly polluted.
    a. The drainage ditch leading from the railroad yards is carrying material toxic to benthic invertebrates. No animals were collected or observed at Station 1.
    b. North Wilson Creek receives the toxic material from the railroad yards. The benthic invertebrate population, as reflected by collections at Station 1a, exhibit a polluted environment--no sensitive forms were collected.
    c. Bottom dwelling invertebrates which are sensitive to organic pollution were not collected in Jordan Creek, Fassnight Creek, or in Wilson Creek below the confluence of Jordan and Fassnight Creeks.
    d. No sensitive benthic forms were collected immediately above the sewage treatment plant.
2. The sewage treatment plant effluent is grossly polluting Wilson Creek from the treatment plant to the mouth of Terrell Creek, a distance of 6.7 river miles.
    a. Rader Spring, as reflected by the benthic collections, is contributing to this degraded condition.
3. Water quality in Wilson Creek improves slightly from the mouth of Terrell Creek to the mouth of Wilson Creek--a distance of 1.38 river miles. Benthic invertebrate collections indicate Terrell Creek dilutes the pollution laden water of Wilson Creek.

4. Benthic samples collected at all stations on the James River exhibit a diverse population of bottom dwelling invertebrates.
   a. Benthic samples of bottom dwelling invertebrates above the confluence of the James River and Wilson Creek reflect good water quality. These collections were composed of more than 50 percent sensitive forms and less than 10 percent tolerant forms.
   b. Invertebrate collections below the confluence of the James River and Wilson Creek (Stations 40 and 41) reflect degraded water. Sensitive forms represented less than 15 percent of the invertebrate collection while tolerant forms represented as much as 30 percent.
5. Sensitive fish food organisms were not completely eliminated below the confluence of James River and Wilson Creek. Other fish food organisms were present in sufficient quantities to sustain a good mixed fauna of fish; sensitive forms decreased in number while tolerant forms increased.
6. Benthic invertebrate collections at Station 44 (39.5 river miles below the confluence of James River and Wilson Creek) reflected recovered conditions.

INTRODUCTION AND METHODS

The benthic study was conducted in the Wilson Creek watershed and the James River above and below the confluence of Wilson Creek and the James River. These data are intended to:

(1) Characterize the water quality of Wilson Creek flowing through and from the metropolitan area of Springfield, Missouri.

(2) Determine the effect of the effluent from a sewage treatment plant on the water quality in Wilson Creek and the James River.

Stations for the benthic study were selected to coincide closely with stations selected for chemical, physical, and hydrological parameters, and yield a good representation of the benthic life of the respective streams. Benthic station location number, river mile, and description appear in Table 1. Benthic samples were collected in March and September 1968. All benthic samples were taken in riffle areas with a square-foot (Surber) sampler (2). A benthic sample was a composite of three, one-square-foot samples. The collected samples were screened on a No. 30, U. S. standard series sieve and preserved in a 5 percent formalin solution. The samples were hand-picked, and organisms were keyed to genera using Edmonson (5), Johannsen (14,15,16,17), Mason (19), Pennak (21), Thomsen (25), and Usinger (27).

DISCUSSION AND RESULTS

The aquatic environment, whether it be flowing or static, is known to support a variety of plants and animals (1,13,22,23). Changes in the environment will stimulate changes in the population. This shift in population of aquatic organisms within the aquatic community is thus something of a monitor of water quality (4,6,10,12,13,22).

It is well known that an unaltered or clean stream or river has a somewhat specific type of fauna (7,10,22). Each variety of bottom dwelling animal possesses a definite response to changes in the environment, some being more sensitive and others more tolerant to change. A particular environment will support a particular community of aquatic organisms best suited for that environment. A change in environment may involve only a change in relative abundance of individuals or shifts in species dominance or, more drastically, a change in both number of kinds and number of individuals.

Mild pollution as a change in the environment will often eliminate only the most sensitive or intolerant forms (12). As the strength of the pollutant increases, the organisms are eliminated in the order of their sensitivity. Often the pollutant will supplement the diet of the surviving animals, thus they increase in number as space is provided by elimination of sensitive forms. This response has often been observed and has given rise to the fact that clean or unpolluted streams support a wide variety of animals but relatively few of each variety; whereas, a polluted environment will support only a few tolerant varieties of organisms, each of which may be represented by many individuals due to increased living space and increased food supply (18,26). Thus, an aquatic environment of poor quality will support only a few kinds of tolerant organisms compared to an environment of high water quality, which will support a wide variety of clean water associated organisms as well as tolerant forms (3,7,8,9,11). Benthic organisms were classified in this study according to their response to pollutants (Figures 3,4,5,6,7,8) (1,3,4,6,7,8,9,11,12,20,23,24).

Wilson Creek originates within the city limits of Springfield, Missouri, thus receiving runoff from city streets along with railroad yard washings and runoff from numerous other industries and activities. Further along the course of the creek, a sewage treatment plant adds its effluent to the flow. Thus, Wilson Creek is receiving many pollutants as reflected by the bottom animal population (Figures 2,4,8).

The drainage ditch, Station 1, leading from the railroad yards to North Wilson Creek is receiving highly toxic pollutants which eliminated all bottom animals (Figure 2). However, it appears to undergo a certain amount of natural stream purification or be diluted in North Wilson Creek as Station 1a had a variety of benthic animals present (Figure 2); but they were almost all tolerant and intermediate forms (Figures 5,7). Jordan Creek receives wastes from a railroad yard, a variety of cooling water discharges, wastes from a fertilizer plant, and runoff from city streets; and the water quality is somewhat degraded as reflected by the number and kinds of organisms present (Figures 2,7). Fassnight Creek is receiving some waste as reflected by the benthic animals (Figures 2,5,7). Here again, as in Jordan and North Wilson Creeks, no sensitive (clean water associated) forms were collected. Wilson Creek at Station 12, which is below the confluence of Fassnight Creek and Jordan Creek, also reflects water of degraded quality. No sensitive organisms were collected. Bottom dwelling animals collected from North Wilson Creek, Jordan Creek, and Fassnight Creek were all intermediate (faculative) and tolerant forms. It thus reflects the fact that all three of these creeks are receiving pollutants of some sort.

Comparing the stations above and below the sewage treatment plant (Stations 14 and 21 respectively) illustrates gross pollution below the sewage treatment plant. Eleven different kinds of bottom dwelling invertebrates were collected above the plant while only three different kinds were collected below the plant (Figure 2). Above the plant, 70 organisms per square foot were collected as compared to 853 organisms collected below the plant. All organisms collected below the plant were tolerant forms (Figures 5,7) while only 17 percent of those collected above the plant were tolerant.

During this study, South Creek was flowing into a sinkhole above the sewage treatment plant and thus had no effect on Wilson Creek. South Creek reflected water of reasonable quality as a balanced complement of sensitive, intermediate, and tolerant bottom dwelling invertebrates were collected.

Wilson Creek at Station 24 (Rader Bridge), located approximately two miles below the sewage treatment plant, illustrated a polluted environment. Ninety-seven percent of the benthic invertebrates collected were of the tolerant form (Figures 5,7). Rader Spring flow enters Wilson Creek downstream approximately 0.2 miles from Rader Bridge; here again, the vast majority (98 percent) of benthic invertebrates collected were tolerant forms. Rader Spring thus does little to improve the quality of Wilson Creek. During this study, the average flow at Rader Bridge on Wilson Creek was 11.5 cfs and the average flow of Rader Spring was 17.4 cfs.

Samples collected at Station 27, approximately two miles downstream from Rader Spring, reflected almost the same conditions as the samples collected at Rader Bridge. Here again, 98 percent of the benthic invertebrates collected were of the tolerant forms (Figures 5,7).

Terrell Creek flows into Wilson Creek approximately 1.4 miles below Station 27 (6.7 miles below the sewage treatment plant) and provides quality improvement through dilution. Average flow during this study was 39.0 for Station 27 and 6.2 cfs for Terrell Creek at State Road ZZ. Benthic invertebrates collected at State Road ZZ on Terrell Creek reflected water of high quality. Only three percent of the organisms collected were represented by tolerant forms.

Manley Ford on Wilson Creek (Station 30) is approximately 0.4 miles below the mouth of Terrell Creek (7.0 miles below the sewage treatment plant). Benthic invertebrate collections illustrated the effect of Terrell Creek on Wilson Creek; tolerant forms represented only 60 percent of the forms collected (Figures 5,7); the number per square foot increased by 40, and the number of kinds increased by 15--

more than doubling the kinds found upstream (Figure 2). Thus, the water quality at Manley Ford is somewhat improved but still degraded.

The mouth of Wilson Creek is 1.0 miles below Manley Ford, and the benthic population here reflected more recovery. However, the invertebrate population was still represented by 55 percent tolerant forms and only 12 percent sensitive forms.

Flow from Wilson Creek enters the James River at river mile 70.5. During this investigation, flow in the James River was equal to or greater than the flow from Wilson Creek. Thus, the pollutants carried into the James River by Wilson Creek were diluted. However, the benthos did reflect some degradation or enrichment when a comparison was made of samples collected above and below the confluence of Wilson Creek (Figures 3,8). By using other types of comparison, no significant differences in quality could be ascertained, as illustrated by Figure 1. No apparent real difference can be seen when comparing the number per square foot and the number of kinds in the above and below stations. However, when comparing the diversity of the community of invertebrates (Figure 3) of stations above and below the confluence of James River and Wilson Creek, it can be seen that the number of sensitive organisms decrease drastically. Figure No. 6 illustrates the percent composition of sensitive and tolerant forms collected and points out the fact that sensitive forms are reduced considerably at both Station 40, which is 2.3 river miles below the mouth of Wilson Creek, and at Station 41, which is 5.5 river miles below the confluence of Wilson Creek and

James River. Tolerant forms increased in number at both of the stations (Figures 6,8). The relative abundance of benthic invertebrates collected from the James River above and below the Wilson Creek confluence did not change significantly (Figures 1,3); however, the shift in the number of sensitive forms and the tolerant forms indicates pollution of a mild nature. The pollutants are not eliminating the sensitive forms altogether; the pollutants are effecting a shift in the species dominance; tolerant forms were being favored while the sensitive forms were being restricted.

For control purposes, benthic organisms were collected from Finley Creek in March 1968. Finley Creek is a tributary to James River and enters James River at river mile 57. These data indicate that no deleterious effect on the James River is caused by Finley Creek.

Station 44, located near Galena, Missouri (river mile 31), is 39.5 river miles below the confluence of Wilson Creek and James River. The benthic invertebrate collections reflected recovery of the water quality. Sensitive forms constituted approximately 50 percent of the collections, while tolerant forms constituted approximately 5 percent of the benthic collections at Station 44 (Figures 3,6). A comparison of invertebrate collections from the control stations (Nos. 33,35,39) with those taken at Station 44 illustrated the fact that recovery had occurred.

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Figure 8 Benthic Organisms - Composite Graph James River

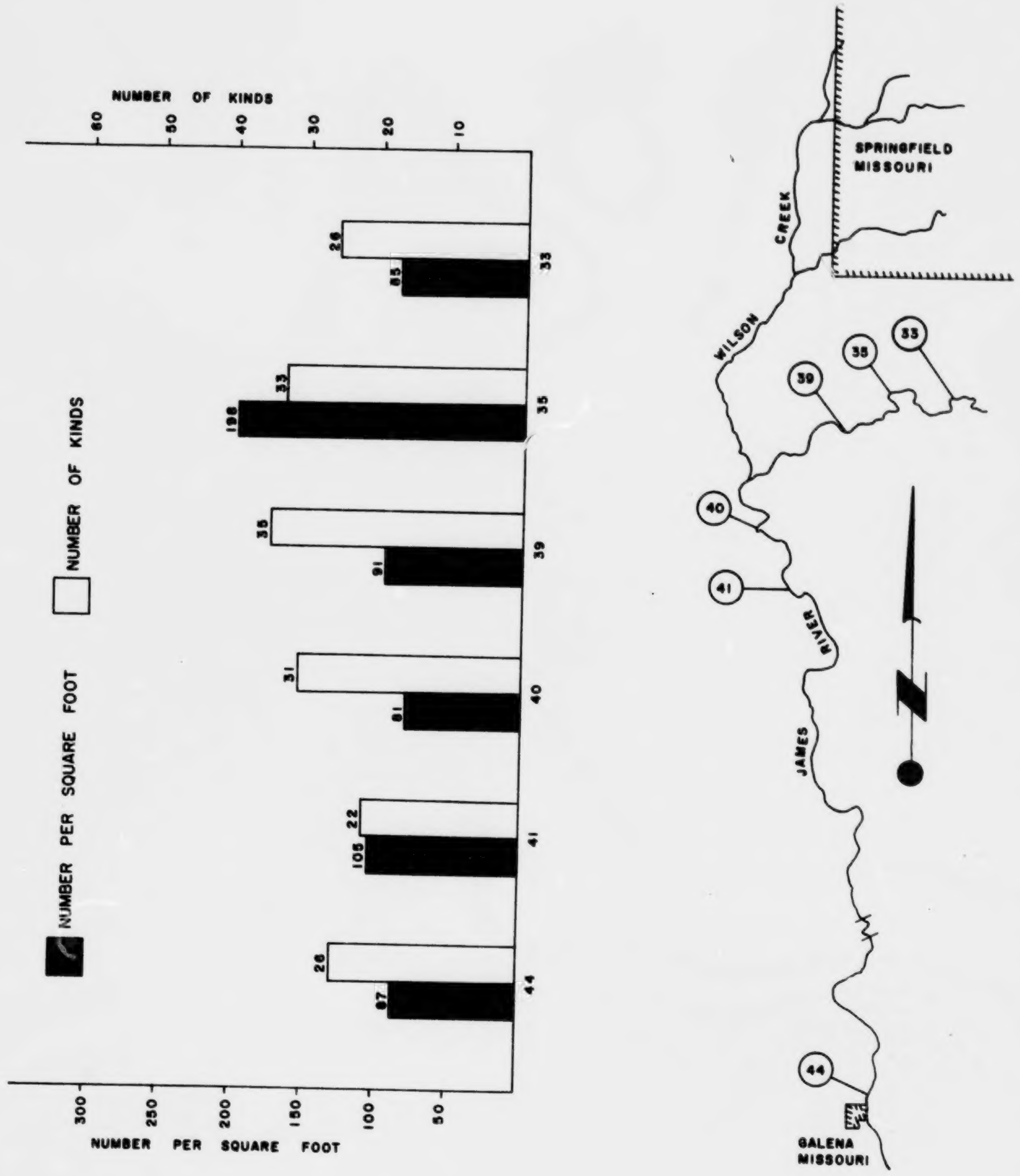


FIGURE I - BENTHIC ORGANISMS - MARCH & SEPTEMBER, 1968
JAMES RIVER, SPRINGFIELD, MISSOURI

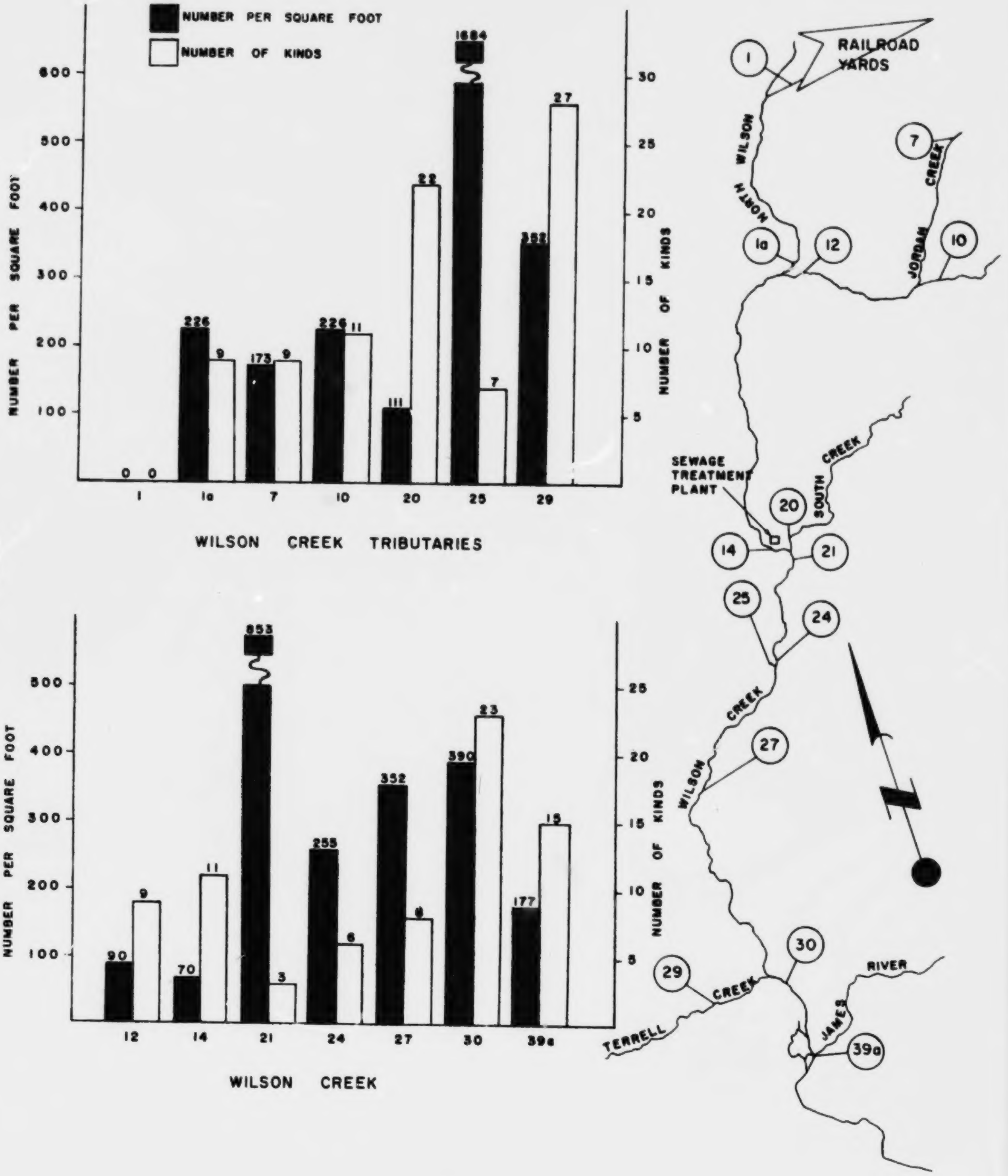


FIGURE 2 - BENTHIC ORGANISMS
WILSON CREEK & TRIBUTARIES, SPRINGFIELD, MISSOURI
MARCH & SEPTEMBER, 1968

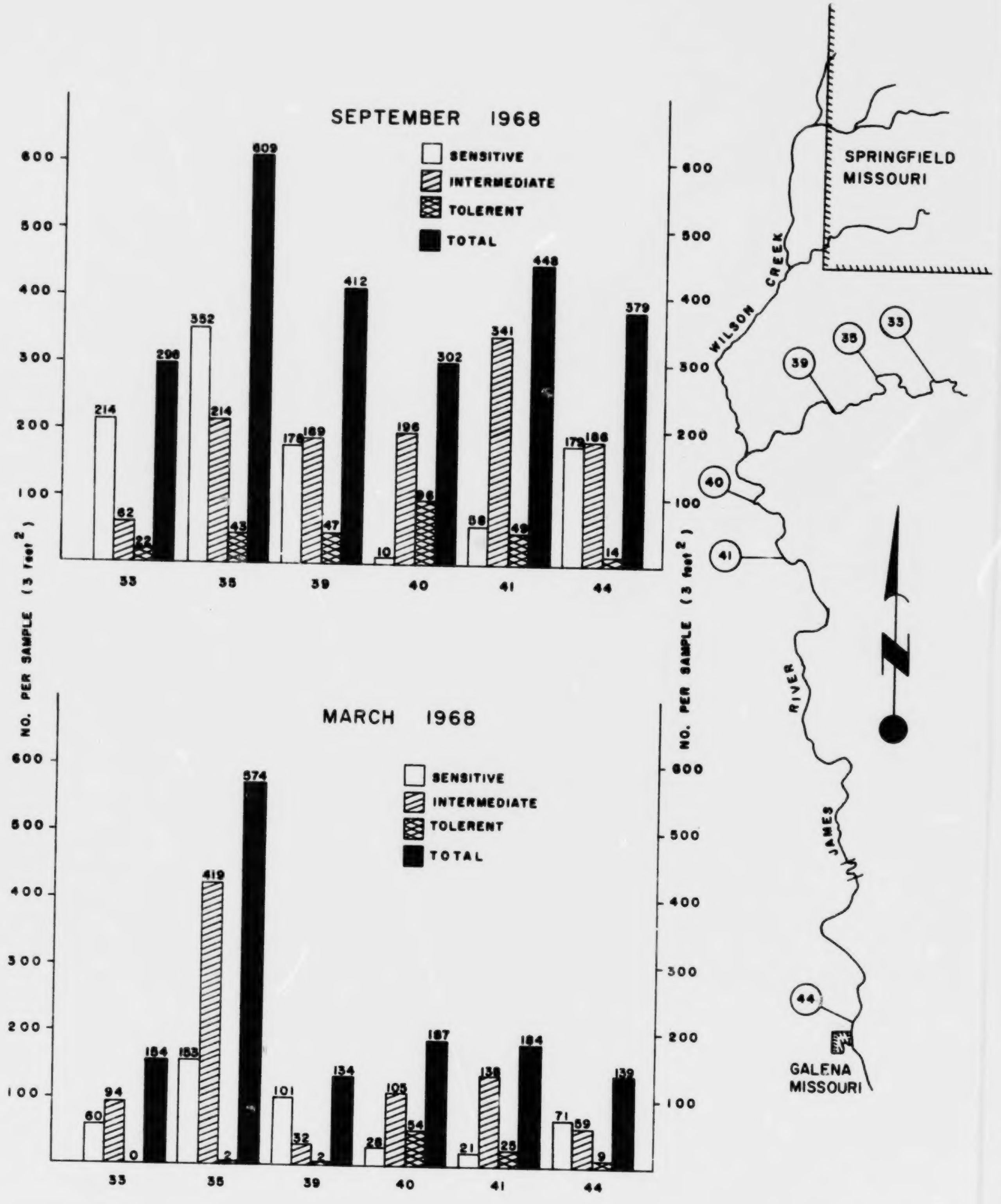


FIGURE 3 - BENTHIC ORGANISMS - COUNT & CLASSIFICATION
JAMES RIVER, SPRINGFIELD, MISSOURI
MARCH & SEPTEMBER, 1968

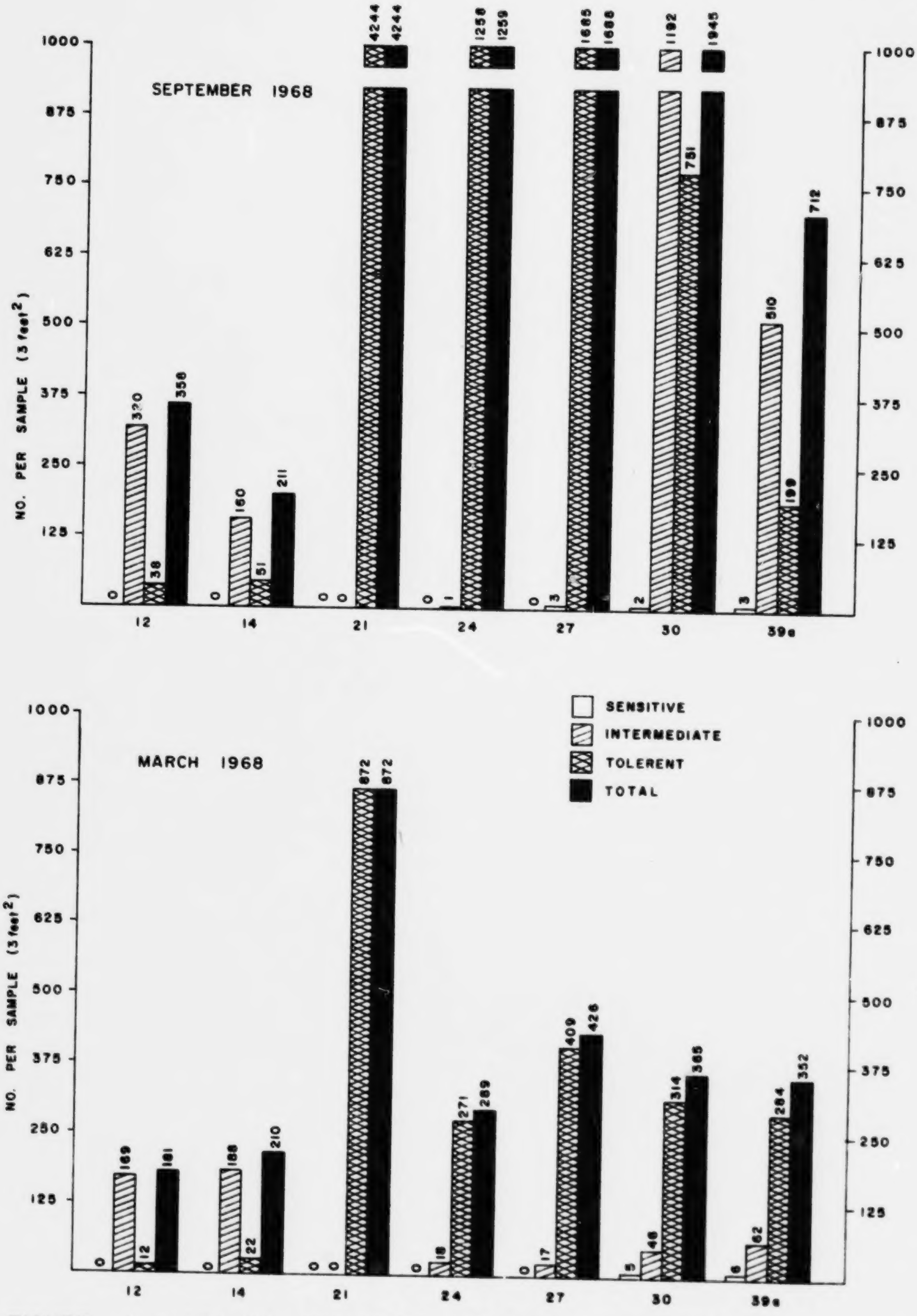


FIGURE 4 - BENTHIC ORGANISMS - COUNT & CLASSIFICATION
WILSON CREEK, SPRINGFIELD, MISSOURI
MARCH & SEPTEMBER, 1968

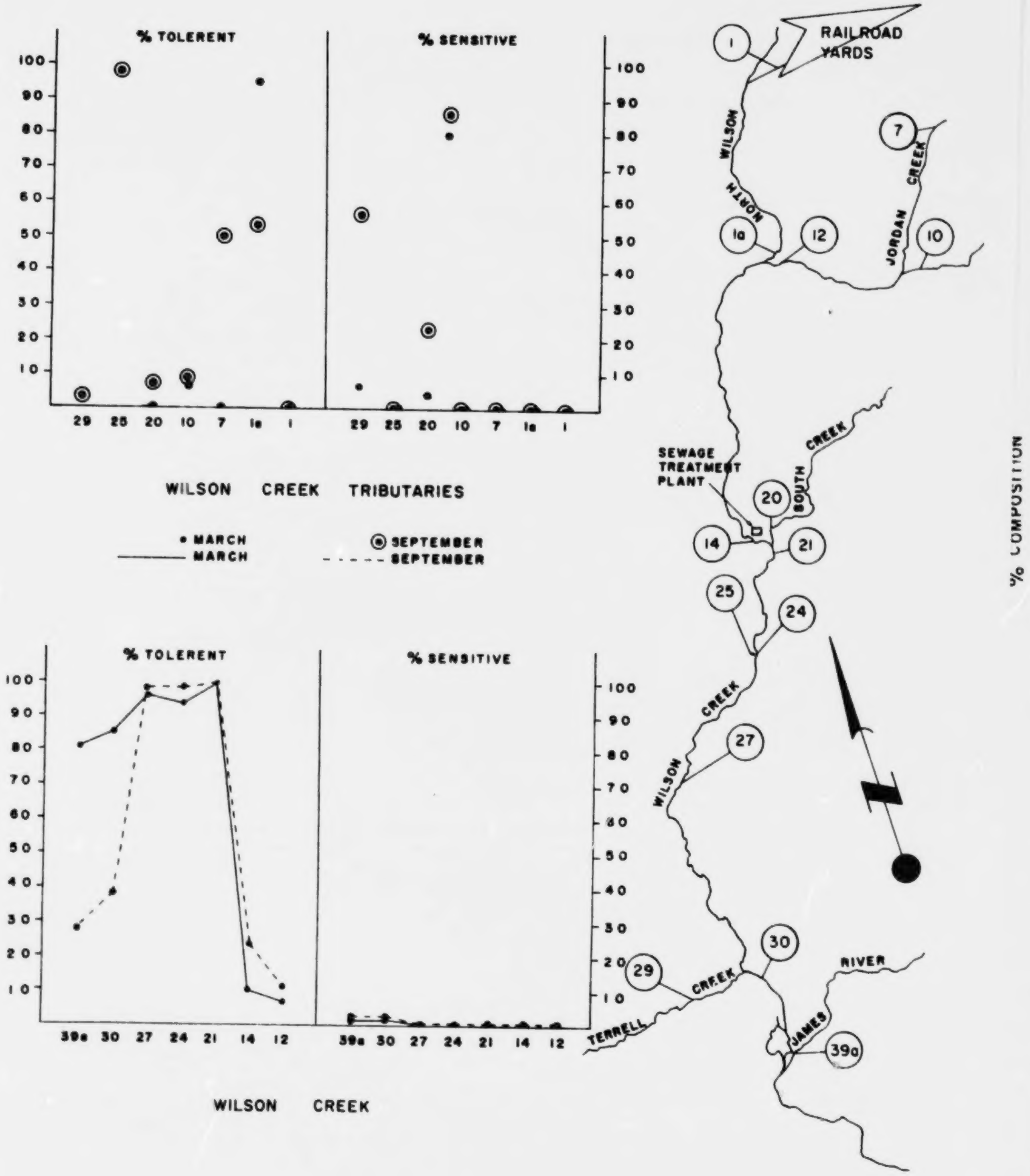
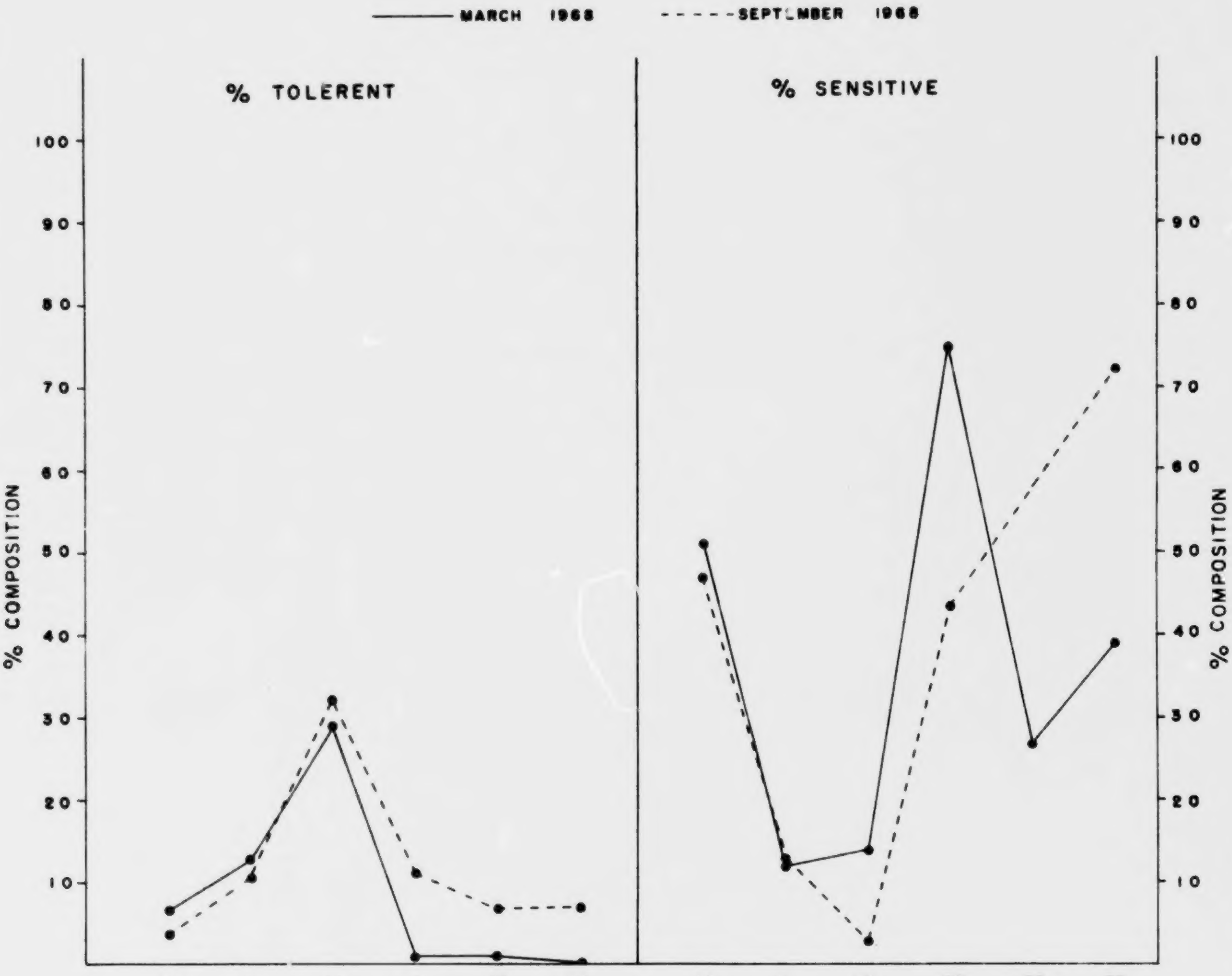


FIGURE 5 - BENTHIC ORGANISMS - PER CENT COMPOSITION
WILSON CREEK & TRIBUTARIES, SPRINGFIELD, MISSOURI
MARCH & SEPTEMBER, 1968



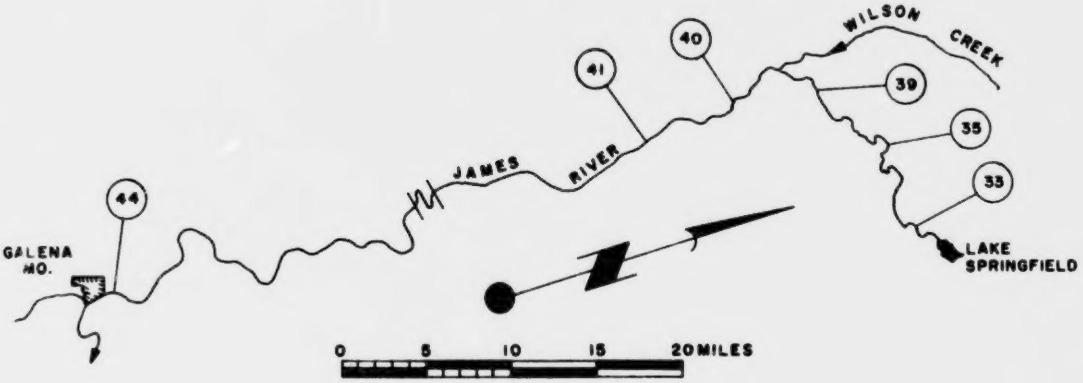

WILSON CREEK
40
41
39
35
33
JAMES RIVER
44
GALENA MO.
LAKE SPRINGFIELD
0
5
10
15
20 MILES

FIGURE 6 - BENTHIC ORGANISMS - PER CENT COMPOSITION
JAMES RIVER, SPRINGFIELD, MISSOURI
MARCH & SEPTEMBER, 1968

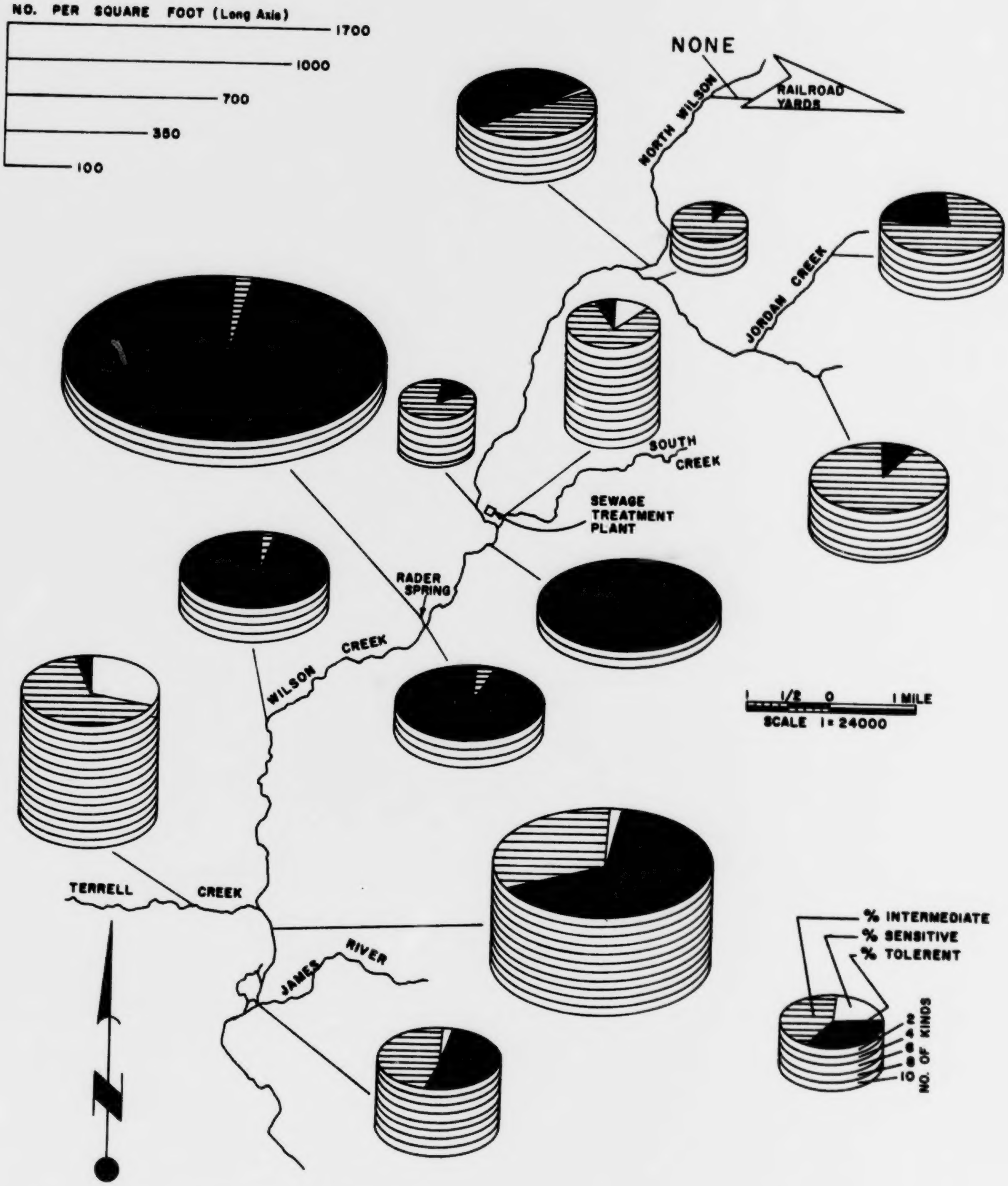

NO. PER SQUARE FOOT (Long Axis)
1700
1000
700
350
100
NONE
RAILROAD YARDS
NORTH WILSON
JORDAN CREEK
SOUTH CREEK
SEWAGE TREATMENT PLANT
RADER SPRING
WILSON CREEK
1 1/2 0 1 MILE
SCALE 1=24000
TERRELL CREEK
JAMES RIVER
% INTERMEDIATE
% SENSITIVE
% TOLERENT
2
4
6
8
10
NO. OF KINDS

FIGURE 7 - BENTHIC ORGANISMS - MARCH & SEPTEMBER, 1968
WILSON CREEK & TRIBUTARIES, SPRINGFIELD, MISSOURI

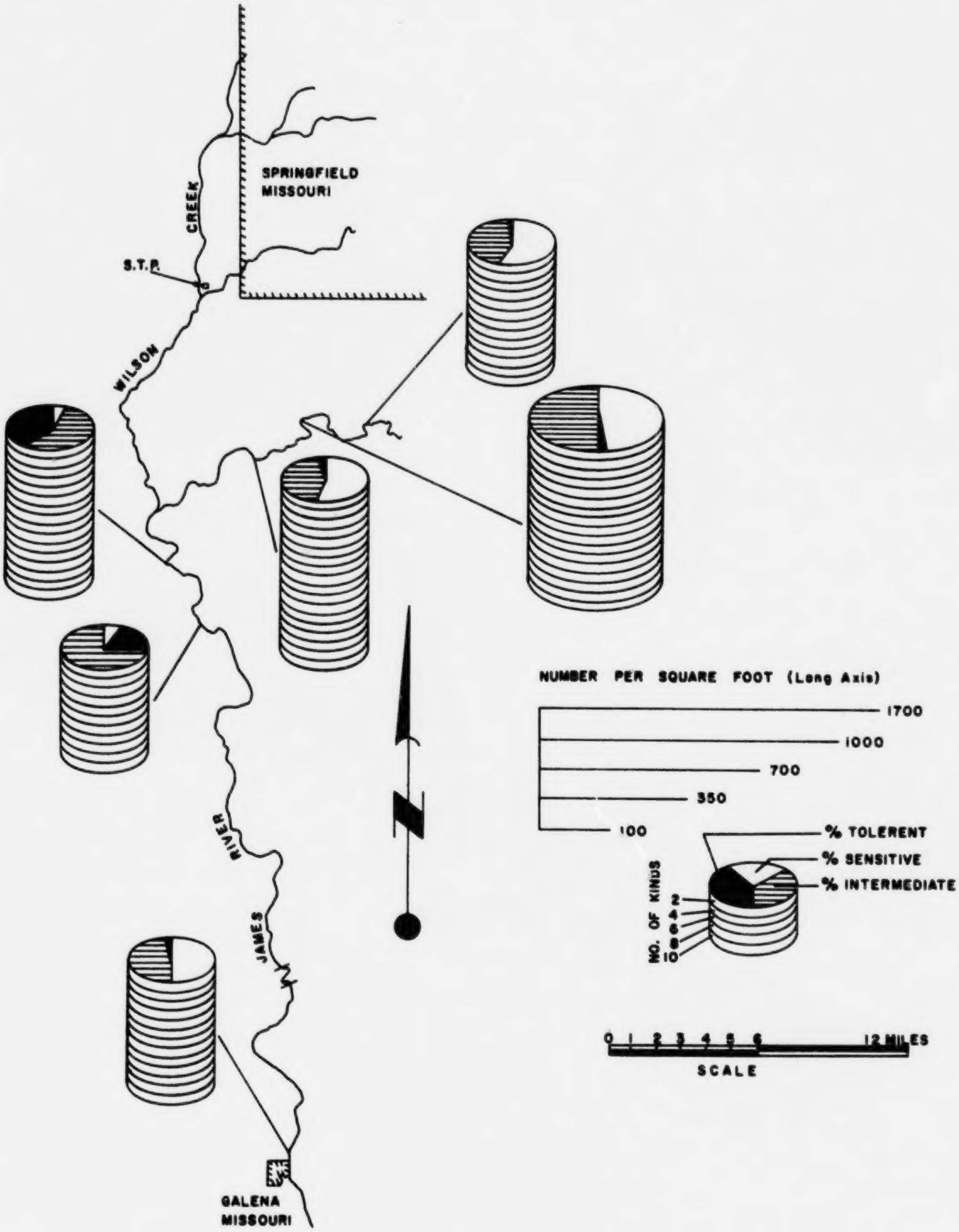

SPRINGFIELD
MISSOURI
CREEK
S.T.P.
WILSON
RIVER
JAMES
GALENA
MISSOURI
NUMBER PER SQUARE FOOT (Long Axis)
1700
1000
700
350
100
% TOLERENT
% SENSITIVE
% INTERMEDIATE
NO. OF KINDS
2
4
6
8
10
0 1 2 3 4 5 6 12 MILES
SCALE

FIGURE 8 - BENTHIC ORGANISMS - MARCH & SEPTEMBER, 1968
JAMES RIVER, SPRINGFIELD, MISSOURI

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Table 3	Bottom Animals, Wilson Creek and Tributaries Number Per Sample
Table 4	Bottom Animals, James River Number Per Sample

Table No. 1

Station Number	River* Mile	Description and Location
1	16.30	Drainage ditch from railroad depot yards
1a	13.00	North Wilson Creek at Highway 13 above confluence of Wilson Creek and North Wilson Creek
5a	16.92	Jordan Creek just below railroad depot yards
10	15.50	Fassnight Creek 1 mile above mouth
12	12.79	Wilson Creek at Highway 13
14	8.30	Wilson Creek 0.1 mile above sewage treatment plant
20	8.20	South Creek above mouth
21	7.90	Wilson Creek 0.1 mile below sewage treatment plant
24	6.43	Wilson Creek at Rader Bridge
25	6.24	Rader Spring
27	4.43	Wilson Creek at north edge of National Battlefield
29	2.13	Terrell Creek at Highway 22
30	1.00	Wilson Creek at Manley Ford
39a	0.00	Mouth of Wilson Creek (mile 70.5 on James River)
33	81.10	James River 1 mile below Lake Springfield
35	77.00	James River at River Downs Road
39	72.70	James River at Nelson Mill Bridge
40	68.20	James River at Highway 14
41	65.00	James River at Bernet's Farm
44	31.00	James River at Galena, Missouri

* In the Wilson Creek watershed, all river mile measurements are from the mouth of Wilson Creek.

Table No. 2

Bottom Animals, Wilson Creek

Number per Sample (3 ft^2)

	March 1968							September 1968						
Station No.	12	14	21	24	27	30	39a	12	14	21	24	27	30	39a
SENSITIVE ORGANISMS														
Plecoptera (Stoneflies)														
Neophasganophora	-	-	-	-	-	2	-	-	-	-	-	-	-	-
Perlesta	-	-	-	-	-	1	-	-	-	-	-	-	-	-
Megaloptera (Dobsonflies)														
Corydalus cornutas	-	-	-	-	-	-	-	-	-	-	-	-	1	1
Trichoptera (Caddis flies)														
Cheumatopsyche	-	-	-	-	-	-	-	-	-	-	-	-	1	-
Ephemeroptera (Mayflies)														
Isonychia	-	-	-	-	-	-	1	-	-	-	-	-	-	1
Psuedocloeon	-	-	-	-	-	2	-	-	-	-	-	-	-	-
Total	0	0	0	0	0	5	1	0	0	0	0	0	2	2
Kinds	0	0	0	0	0	3	1	0	0	0	0	0	2	2
INTERMEDIATE ORGANISMS														
Diptera (Midges)														
Pentaneura	-	-	-	-	-	-	-	-	-	-	-	-	257	-
Simulium	-	-	-	-	-	-	-	-	-	-	-	-	5	-
Cardiocladius	-	-	-	-	-	-	-	-	48	-	-	-	-	-
Cricotopus	28	186	-	2	5	-	14	79	42	-	-	-	101	86
Procladius	-	-	-	-	-	-	-	-	-	-	-	-	103	-
Polypedilum	-	-	-	-	1	-	-	87	18	-	-	-	614	304
Orthocladius	140	-	-	16	11	29	54	51	36	-	-	-	-	-
Nanocladius	-	-	-	-	-	6	-	-	-	-	-	-	-	-
Isopoda (Aquatic Sow Bugs)														
Asellus	-	-	-	-	-	1	-	-	-	-	-	-	-	-
Lirceus	-	-	-	-	-	-	-	-	-	-	-	1	1	-
Ephemeroptera (Mayflies)														
Stenonema	-	-	-	-	-	1	-	-	-	-	-	-	-	1
Baetis	-	-	-	-	-	8	-	-	-	-	-	-	-	2

Table No. 2 (Continued)

Bottom Animals, Wilson Creek

Number per Sample (3 ft^2)

	March 1968							September 1968						
Station No.	12	14	21	24	27	30	39a	12	14	21	24	27	30	39a
INTERMEDIATE ORGANISMS														
Gastropoda (Snails)														
Helisoma	-	-	-	-	-	1	-	-	-	-	-	-	6	-
Tricladida (Planarian)														
Dugesia	1	1	-	-	-	-	-	103	-	-	1	2	97	116
Decapoda (Crayfishes)														
Orconectes virilis	-	1	-	-	-	-	-	-	-	-	-	-	8	1
Odonata (Dragonflies)														
Argia	-	-	-	-	-	-	-	-	16	-	-	-	-	-
Total	169	188	0	18	17	46	68	320	160	0	1	3	1,192	510
Kinds	3	3	0	2	3	6	2	4	5	0	1	2	9	6
TOLERANT ORGANISMS														
Hirudinea (Leeches)	-	17	1	-	-	-	-	6	25	1	1	-	-	-
Oligochaeta (Worms)	4	5	851	268	405	292	268	18	4	3,263	237	328	742	137
Lumbriculus	6	-	-	-	-	-	-	-	-	-	-	-	5	-
Gastropoda (Snails)														
Physa	6	-	-	-	-	4	2	-	16	-	-	1	34	-
Diptera (Midges)														
Chironomus larvae	-	-	20	3	4	8	-	14	6	840	1,000	1,346	-	60
Chironomus pupae	-	-	-	-	-	-	-	-	-	140	-	10	-	-
Tendipes	-	-	-	-	-	-	14	-	-	-	-	-	-	-
Total	16	22	872	271	409	304	284	38	51	4,244	1,238	1,685	781	197
Kinds	3	2	3	2	2	3	3	3	4	4	3	4	3	2
Grand Total	185	210	872	289	426	355	353	358	211	4,244	1,239	1,688	1,975	709
Total Number Kinds	6	5	3	4	5	12	6	7	9	4	4	6	14	10

Table No. 3

Bottom Animals, Wilson Creek Tributaries

Number per Sample (3 ft^2)

	March 1968							September 1968						
Station No.	1	1a	7	10	20	25	29	1	1a	7	10	20	25	29
SENSITIVE ORGANISMS														
Coleoptera (Beetles)														
Stenelmis	-	-	-	-	37	-	-	-	-	-	-	21	-	-
Psephenus herricki	-	-	-	-	21	-	1	-	1	-	-	47	-	3
Plecoptera (Stoneflies)														
Neophasganophora	-	-	-	-	-	-	11	-	-	-	-	1	-	19
Perlesta	-	-	-	-	-	-	1	-	-	-	-	-	-	-
Acroneuria	-	-	-	-	-	-	-	-	-	-	-	-	-	1
Megaloptera (Dragonflies)														
Corydalus cornutus	-	-	-	-	1	-	-	-	-	-	-	9	-	-
Odonata (Dragonflies)														
Gomphus	-	-	-	-	-	-	-	-	-	-	-	1	-	-
Libellula	-	-	-	-	-	-	-	-	-	-	-	1	-	-
Trichoptera (Caddis flies)														
Chimarra	-	-	-	-	-	-	1	-	-	-	-	-	-	12
Cheumatopsyche	-	-	-	-	-	-	9	-	-	-	-	19	-	266
Polycentropus	-	-	-	-	-	-	1	-	-	-	-	-	-	-
Hydropsyche	-	-	-	-	-	-	-	-	-	-	-	-	-	59
Ephemeroptera (Mayflies)														
Pseudocloeon	-	-	-	-	-	-	23	-	-	-	-	-	-	36
Heptagenia	-	-	-	-	-	-	1	-	-	-	-	-	-	-
Isonychia	-	-	-	-	-	-	4	-	-	-	-	-	-	4
Ephemerella	-	-	-	-	-	-	1	-	-	-	-	-	-	-
Tricorythodes	-	-	-	-	-	-	-	-	-	-	-	19	-	-
Total	0	0	0	0	59	0	53	0	1	0	0	118	0	400
Kinds	0	0	0	0	3	0	10	0	1	0	0	8	0	8
INTERMEDIATE ORGANISMS														
Ephemeroptera (Mayflies)														
Stenonema	-	-	-	-	24	-	2	-	2	-	-	25	-	25
Baetis-	-	-	-	-	-	-	47	-	-	-	-	191	-	73

Table No. 3 (Continued)

Bottom Animals, Wilson Creek Tributaries

Number per Sample (3 ft^2)

	March 1968							September 1968						
Station No.	1	1a	7	10	20	25	29	1	1a	7	10	20	25	29
							INTERMEDIATE ORGANISMS							
Tricladida (Planarian)														
Dugesia	-	-	-	33	97	2	5	-	5	-	3	6	9	64
Pelecypoda (Clams)														
Sphaerium	-	-	-	-	8	-	-	-	-	-	-	3	46	-
Isopoda (Aquatic Sow Bugs)														
Lirceus	-	-	-	-	-	-	16	-	-	-	-	-	-	58
Ascellus	-	-	-	-	-	-	83	-	-	-	-	-	-	18
Gastropoda (Snails)														
Goniobasis	-	-	-	-	-	-	-	-	-	-	-	-	-	1
Amphipoda (Scud)														
Gammarus	-	-	-	-	-	17	-	-	-	-	-	-	-	-
Decapoda (Crayfish)														
Orconectes sp.	-	-	-	-	-	-	-	-	-	-	-	5	-	-
Orconectes virilis	-	-	-	-	-	-	1	-	-	-	2	3	-	8
Odonata (Dragonflies)														
Argia	-	-	1	14	2	-	-	-	-	-	3	15	-	-
Diptera (Midges)														
Cricotopus (larvae)	-	9	182	832	34	-	560	-	137	249	25	10	-	32
Cricotopus (pupae)	-	-	61	-	13	-	-	-	-	81	-	-	-	-
Polypedilum	-	-	-	16	-	-	-	-	104	-	274	11	-	-
Orthocladius	-	-	-	-	-	-	-	-	201	54	29	-	-	11
Cardiocladius	-	-	-	-	-	-	-	-	67	-	-	-	-	-
Pentaneura	-	-	-	-	-	-	-	-	-	9	27	2	-	-
Chrysops	-	-	-	-	-	-	-	-	-	-	-	1	-	-
Psectrocladius	-	-	-	-	-	-	-	-	-	-	-	9	-	-
Hexatoma	-	-	-	-	-	-	-	-	-	-	-	-	-	1
Tanypodinae	-	-	4	-	-	-	-	-	-	-	-	-	-	-
Total	0	9	248	895	178	19	714	0	516	393	363	281	55	291
Kinds	0	1	4	4	6	2	7	0	6	4	7	12	2	10

Table No. 3 (Continued)

Bottom Animals, Wilson Creek Tributaries

Number per Sample (3 ft^2)

	March 1968							September 1968						
Station No:	1	1a	7	10	20	25	29	1	1a	7	10	20	25	29
TOLERANT ORGANISMS														
Gastropoda (Snails)														
Physa	-	-	-	8	-	62	-	-	58	41	1	1	447	-
Diptera (Midges)														
Chironomus (larvae)	-	-	-	-	-	56	-	-	-	4	-	-	1,298	3
Chironomus (pupae)	-	-	-	-	-	6	-	-	-	-	-	-	20	-
Dicrotendipes	-	-	-	-	-	-	-	-	-	-	-	-	-	3
Hirudinea (Leeches)	-	-	1	19	1	-	-	-	-	-	1	7	1	1
Oligochaeta (Worms)	-	252	1	37	-	17,390	26	-	520	352	21	22	752	6
Lumbriculus	-	-	-	-	-	-	-	-	-	-	12	1	-	-
Total	0	252	2	64	1	17,514	26	0	578	397	35	31	2,518	13
Kinds	0	1	2	3	1	4	1	0	2	3	4	4	5	4
Grand Total	0	261	250	959	238	17,533	793	0	1,095	790	398	430	2,573	704
Total Number Kinds	0	2	6	7	10	6	18	0	9	7	11	24	7	22

Table No. 4

Bottom Animals, James River

Number per Sample (3 ft^2)

	March 1968						September 1968					
Station No.	33	35	39	40	41	44	33	35	39	40	41	44
SENSITIVE ORGANISMS												
Ephemeroptera (Mayflies)												
Isonychia	5	25	4	4	1	14	2	63	61	1	2	41
Heptagenia	1	-	-	-	-	-	-	-	-	-	-	-
Ephemera	-	1	2	-	9	-	2	7	11	-	2	11
Tricorythodes	-	2	-	-	-	-	42	8	-	2	24	15
Ephemerella	-	6	5	8	-	6	-	-	-	-	-	-
Ephoron	-	-	-	1	-	3	-	-	-	1	-	15
Paraleptophlebia	-	-	-	2	-	14	-	-	-	-	-	-
Pseudocloeon	-	-	-	3	5	9	-	-	-	-	-	1
Plecoptera (Stoneflies)												
Neophasganophora	3	2	21	3	-	1	-	-	1	-	-	6
Neoperla	-	8	3	2			-	10	-	-	-	-
Acroneuria	-	-	-	1	-	-	-	-	-	-	-	-
Brachyptera	5	-	-	1			-	-	-	-	-	-
Perlesta	-	4	1	3	4	-	-	-	-	-	-	-
Trichoptera (Caddis flies)												
Hydropsyche	15	1	7	-	-	-	1	2	6	1	-	-
Cheumatopsyche	7	51	4	-	-	-	119	186	74	-	13	4
Chimarra	-	8	14	-	-	-	1	13	11	-	-	-
Unidentified	-	-	1	-	-	-	-	-	-	-	-	-
Coleoptera (Beetles)												
Stenelmis (larvae)	24	38	36	-	-	24	30	86	6	3	13	85
Stenelmis (adult)	-	4	-	-	-	-	-	-	-	-	-	-
Psephenus herricki	-	-	1	-	-	-	-	2	-	-	-	-
Megaloptera (Dobsonflies)												
Corydalus cornutus	-	3	2	-	-	-	18	15	20	1	4	1
Total	60	153	101	28	19	71	215	392	190	9	58	179
Kinds	7	13	13	10	4	7	8	10	8	6	6	9

Table No. 4 (Continued)

Bottom Animals, James River

Number per Sample (3 ft^2)

	March 1968						September 1968					
Station No.	33	35	39	40	41	44	33	35	39	40	41	44
							INTERMEDIATE ORGANISMS					
Ephemeroptera (Mayflies)												
Baetis	11	-	1	3	3	-	8	15	31	43	70	19
Stenonema	2	25	10	29	22	22	17	114	49	28	153	78
Diptera (Midges)												
Simulium	10	14	-	-	-	-	-	-	5	-	-	3
Hexatoma	-	2	-	-	-	-	-	1	1	-	-	-
Tipula	-	1	-	1	-	-	-	-	-	-	-	-
Orthocladius	21	39	6	3	46	14	-	-	-	-	19	7
O. Cricotopus (larvae)	50	212	-	18	38	6	-	-	12	-	26	7
Cricotopus (Pupae)	-	12	-	4	-	1	-	-	-	-	-	-
Chrysops	-	-	2	-	-	-	-	-	-	-	-	-
Spaniotoma	-	-	4	-	2	-	-	-	-	-	-	-
Trichocladius	-	-	-	8	8	-	-	-	-	-	12	-
Polypedilum	-	-	-	-	-	-	22	-	23	63	-	8
Tabanus	-	-	-	-	-	-	1	1	-	-	-	-
Cardiocladius	-	-	-	32	-	-	-	-	-	-	-	-
Procladius	-	-	-	-	2	-	-	-	-	-	-	-
Eukiefferiella	-	-	-	-	2	-	-	-	-	-	-	-
Diamesa	-	74	-	-	-	16	-	-	-	-	-	-
Psectrocladius	-	-	-	-	-	-	-	-	6	-	-	-
Pentaneura	-	-	-	-	-	-	-	-	13	4	-	-
Cryptochironomus	-	-	-	-	-	-	-	-	-	34	-	3
Nanocladius	-	32	-	-	-	-	-	-	-	-	-	-
Odonata (Dragonflies)												
Argia	-	-	-	1	1	-	3	1	-	3	21	-
Tricladida (Planarian)												
Dugesia	-	2	5	-	11	-	4	1	5	32	11	20
Decapoda (Crayfishes)												
Orconectes	-	1	3	2	3	-	6	-	-	24	29	3
Orconectes rustious	-	-	-	-	-	-	-	-	11	-	-	-
Orconectes virilus	-	-	-	-	-	-	-	-	2	-	-	-

Table No. 4 (Continued)

Bottom Animals, James River

Number per Sample (3 ft^2)

	March 1968						September 1968					
Station No.	33	35	39	40	41	44	33	35	39	40	41	44
INTERMEDIATE ORGANISMS												
Gastropoda (Snails)												
Goniobasis	-	5	5	-	-	-	-	13	6	-	-	34
Pleurocera	-	-	1	-	-	-	1	-	9	-	-	2
Pelecypoda (Clams)												
Sphaeriidae	-	-	-	-	-	-	5	37	12	2	-	-
Isopoda (Aquatic Sow Bugs)												
Lirceus	-	-	-	-	-	-	-	-	1	-	-	-
Megaloptera (Dobsonflies)												
Sialis	-	-	-	-	-	-	-	1	-	-	-	-
Total	94	419	37	101	138	59	67	184	186	233	341	184
Kinds	5	12	9	10	11	5	9	9	15	9	8	11
TOLERANT ORGANISMS												
Hirudinea (Leeches)	-	-	-	2	14	3	-	-	-	6	39	1
Diptera (Midges)												
Chironomus	-	-	1	-	-	-	-	-	-	12	-	-
Atherix	-	-	-	-	-	-	-	-	-	1	1	5
Pseudochironomus	-	-	-	-	-	-	15	-	-	-	-	-
Oligochaeta (Worms)	-	2	-	52	11	6	1	5	32	41	9	8
Total	0	2	1	54	25	9	16	5	32	60	49	14
Kinds	0	1	1	2	2	2	2	1	1	4	3	3
Grand Total	154	574	139	183	182	139	298	581	408	302	448	377
Total Number Kinds	12	26	23	22	17	14	19	20	24	19	17	23

APPENDIX C

FISH INVESTIGATION

JAMES RIVER-WILSON CREEK STUDY
Springfield, Missouri

APPENDIX C

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INTRODUCTION

The James River originates in Webster County, Missouri, and flows in a southwesterly direction for approximately 100 miles where it empties into Table Rock Reservoir. The watershed is broadleaf forests and farmland, typically Ozark hill country. The James River is a popular fishing stream and is a primary tributary to Table Rock Reservoir. Recreation is a principal industry of this area.

At river mile 70.5, Wilson Creek joins the James River. The confluence is approximately 10 miles south of the city limits of Springfield, Missouri. Wilson Creek is approximately 15 miles long and originates in the City of Springfield. The watershed is primarily urban. Wilson Creek now has recreational and aesthetic values based upon the establishment of a new national park, Wilson's Creek Battlefield National Park.

For a number of years, intermittent fish kills have occurred on Wilson Creek and the James River below the Wilson Creek confluence. A fish survey was conducted to determine the effects of pollutants discharged from the Wilson Creek watershed on the fish population of the James River.

CONCLUSIONS

1. There were no significant differences in the number of kinds of fish collected at stations on the James River. The James River, from mile 72.7 to 64.0, had an excellent variety of fish typical of a relatively unpolluted stream.
2. Rough fish were more prevalent below the Wilson Creek confluence. Food and game fish decreased below the confluence, but were still adequate to sustain a fishery. Any significant damage to the game fish population caused by pollutants discharged from the Wilson Creek watershed occurred during past fish kills, and thus was temporary.
3. There were no significant differences in the condition factor of bass or catfish collected above and below the Wilson Creek confluence.
4. No fish were collected above stream mile 1.5 on Wilson Creek. Fish could not live in Wilson Creek above stream mile 1.5 due to polluted conditions. Fish collected below stream mile 1.5 on Wilson Creek reflected improved but still degraded conditions.

STREAM INVESTIGATION

A fish survey was conducted from May through August 1968. Methods used in this survey were adapted from work conducted by other investigators (2,9). The survey included the following parameters: (1) Number of species; (2) Catch per unit effort; and (3) Condition of selected species. Fish were collected monthly on the James River from May through August 1968. Samples on Wilson Creek were taken in May and June. Terrell Creek, tributary to Wilson Creek at mile 1.4, was also sampled in May. Samples were collected employing an electro-fishing device (Figure 1).

This device consisted of a fourteen-foot, flat-bottomed boat, 230-volt A.C. portable generator, 60-gallon live tank, and 3- x 4-foot plywood platform with 10-foot adjustable booms and safety railing attached. The electrodes were two pieces of flexible steel conduit 7 1/2 feet long. They were leaded to increase shocking efficiency along the stream bottom. This boom-type shocking device was constructed to insure mobility in the field.

Attempts to use a 20- x 6-foot seine of 1/4-inch mesh proved unsuccessful due to a heavy accumulation of organic debris, large rocks, or deep water. Thus, the boom-type shocker was the sole fish sampling device used during this investigation.

There were eight sampling stations. Three of these stations were on the James River while four were on Wilson Creek. There was also a station on Terrell Creek. The stations on the James River

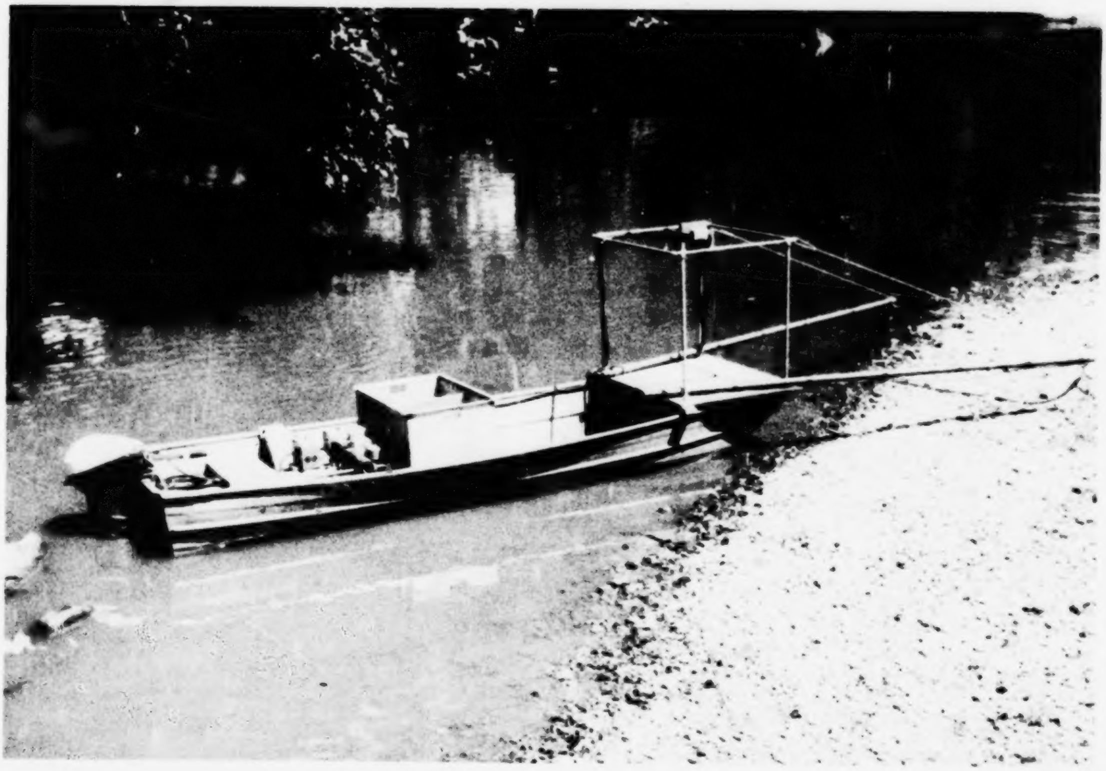


Figure 1 - Electrofishing Device Used on James River Fish Survey

extended from river mile 72.7 to 64.0.[1] Each station consisted of approximately three river miles with two stations (Figure 2) located below the Wilson Creek confluence. The stations on the James River were selected in this manner to include representative types of stream habitat at all three stations. The stations on Wilson Creek extended from stream mile 7.0, approximately 0.75 miles below the sewage treatment plant, to immediately below the mouth of Terrell Creek.

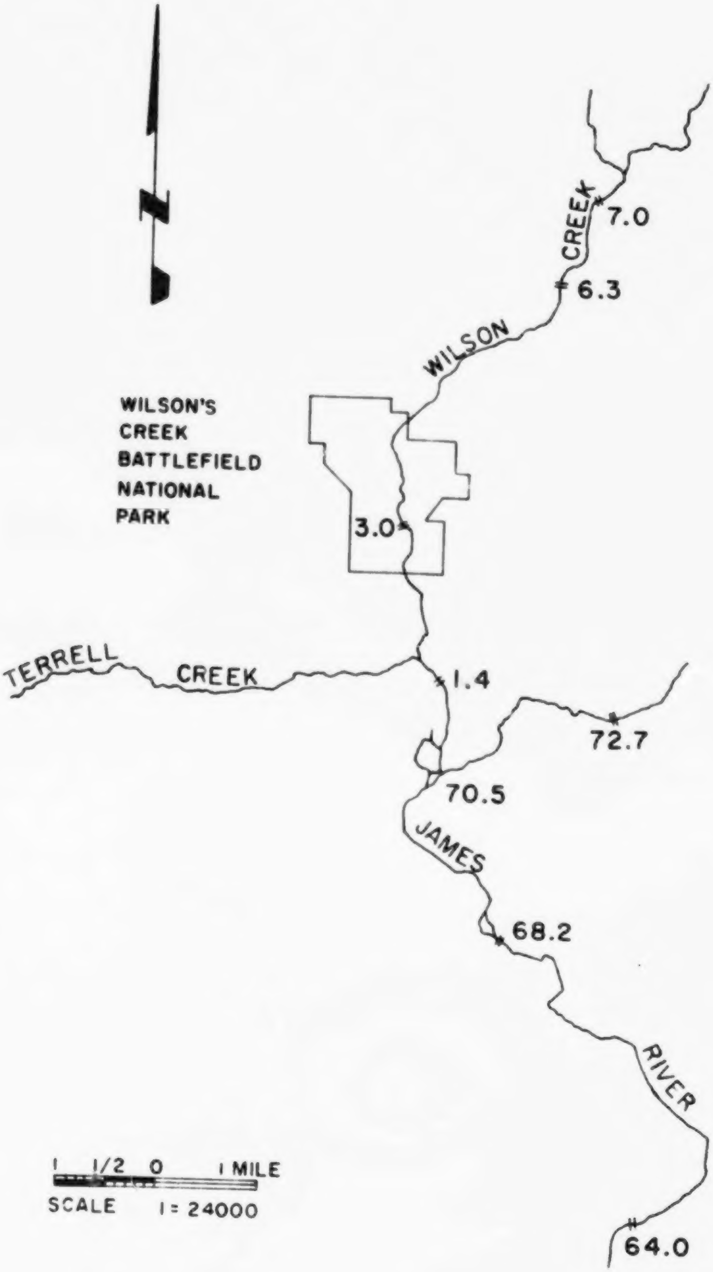
Fish collected at each station were divided into three groups: game, rough, and forage. Table 1 contains a list of the species collected during this investigation.

A total of 7,014 fish representing 43 species[2] were collected during the James River investigation. Figure 3 illustrates the number of species found at stations on the James River, Wilson Creek, and Terrell Creek. There were more species present at Stations 1 and 3 than at Station 2, but the differences were not statistically significant. The James River had an excellent variety of fish typical of a relatively unpolluted warm water stream.

Based upon a thorough knowledge of the habitat and adequate sampling efficiency, there were differences in the abundance of

[1] River miles measured from the confluence of the James River arm and main body of Table Rock Reservoir.

[2] Rainbow trout were collected during this investigation below springs on the James River and Wilson Creek. There is no trout fishery on these streams; however, they were included on the species list.



7.0
CREEK
6.3
WILSON
WILSON'S CREEK BATTLEFIELD NATIONAL PARK
3.0
TERRELL
CREEK
1.4
72.7
70.5
JAMES
68.2
RIVER
1 1/2 0 1 MILE
SCALE 1: 24000
64.0

FIGURE 2 - MAP OF JAMES RIVER AND WILSON CREEK NEAR SPRINGFIELD, MISSOURI.

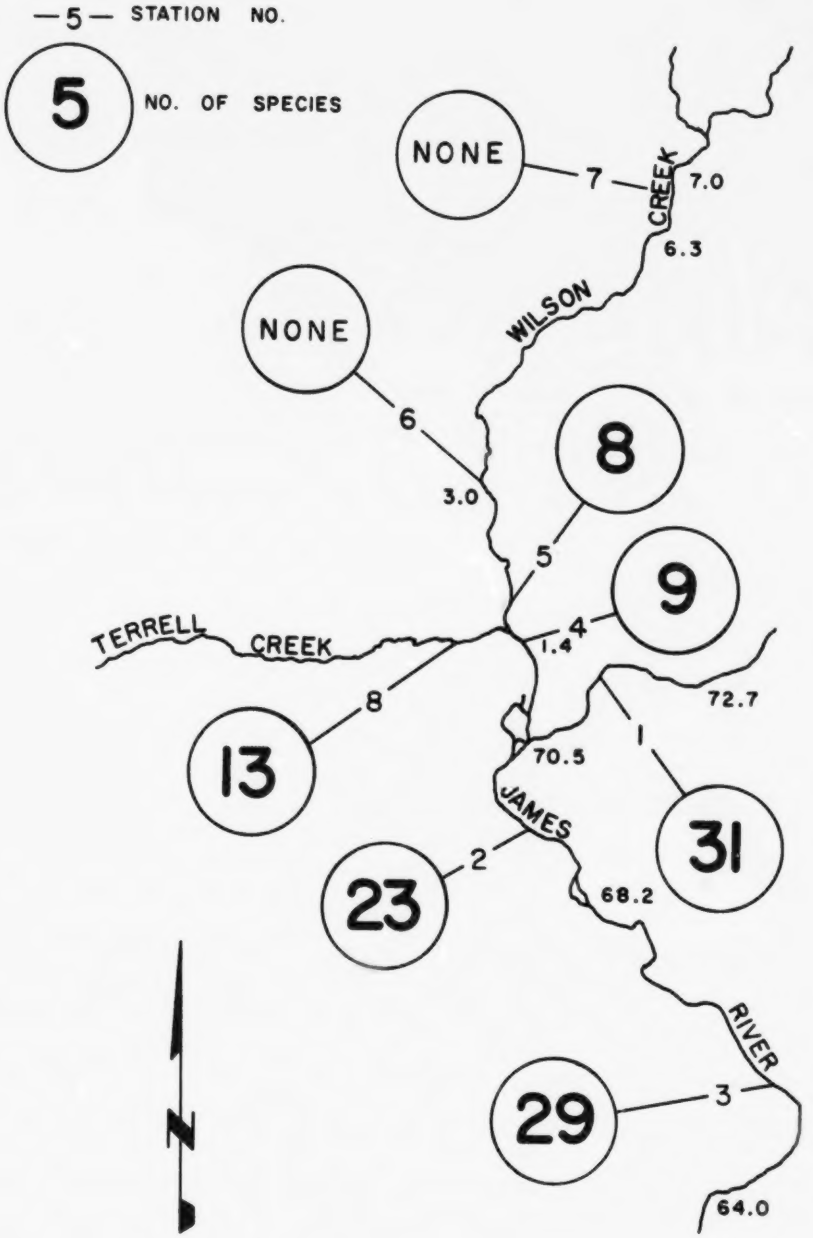

—5— STATION NO.
5 NO. OF SPECIES
NONE
7
CREEK
7.0
6.3
WILSON
NONE
6
3.0
8
5
9
4
1.4
TERRELL
CREEK
8
13
72.7
70.5
1
JAMES
31
2
23
68.2
RIVER
29
3
N
64.0

FIGURE 3 - NUMBER OF SPECIES OF FISH PER STATION.

rough, game, and forage fish at stations on the James River. The number of rough, game, and forage fish collected per hour of electrofishing time (catch per unit effort) at each station is expressed in Figure 4. The increase of available nutrients from Wilson Creek caused a corresponding increase in bottom-attached algae at Station 2. The dominance of rough fish at Station 2 which are omnivorous bottom feeders reflected the fertilization effect of Wilson Creek on the James River (Figure 4). The fertilization of the James River was also reflected downstream. At Station 3, the number of rough, game, and forage fish caught per hour substantially increased, compared to Station 1.

Although the rough fish increased below the Wilson Creek confluence, game fish were still significantly abundant in this area to sustain a fishery (Table 2). Thus, any significant damage to the game fish population of the James River caused by pollutants discharged from the Wilson Creek watershed occurred during past fish kills and thus was temporary.

Desirable food and game fish such as largemouth bass, spotted bass, channel catfish, and bluegill were present at all stations on the James River (Table 2). Catfish and bass comprise a major part of the sport fishery of the James River. A condition factor was calculated for these species collected above and below the Wilson Creek confluence.

The coefficient of condition (condition factor) is a numerical value used to express the relative well-being (i.e., plumpness or fatness) of fishes. It may be used to indicate the suitability of

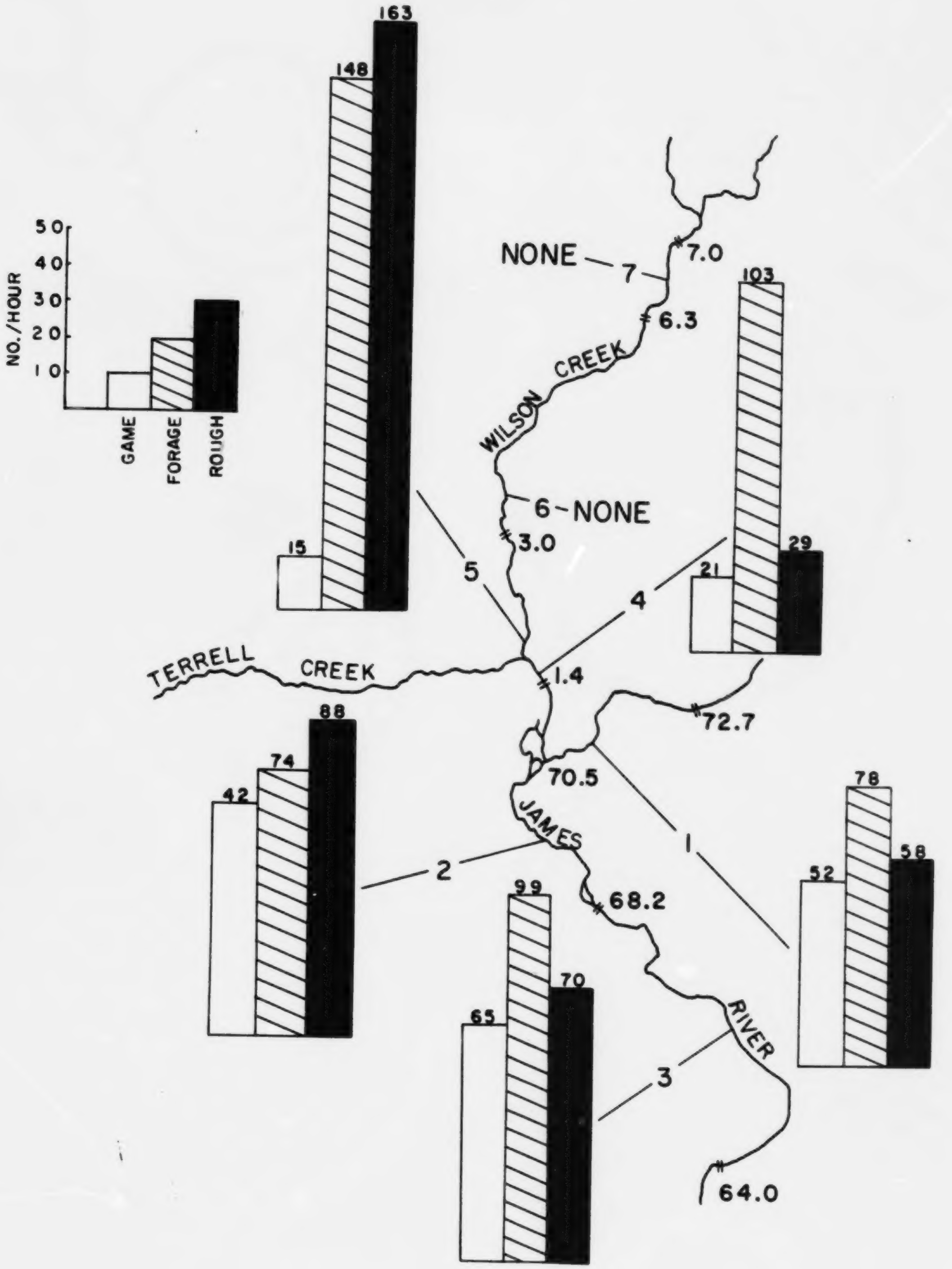


FIGURE 4 - NUMBER OF GAME, ROUGH AND FORAGE FISH CAUGHT PER HOUR AT STATIONS ON JAMES RIVER AND WILSON CREEK, MAY - AUGUST, 1968.

environment or to compare the healthiness of fish from different areas of a stream (8). The formula $K = \frac{W\ (\text{weight}) \times 10^5}{L\ (\text{length})^3}$ was applied to bass and channel catfish taken from the James River. Weight was recorded in grams and length (total) in millimeters.

Other factors which may affect a fish's coefficient of condition are age, sex, and season (4). Taking these factors into consideration, the mean condition factor was calculated for bass and channel catfish taken from three stations during different sampling dates. A series of analyses of variance were performed on the condition factors of these fish, and no significant differences were found between stations on the basis of mean condition factors (Figure 5).

Previous reports (6,7) indicate poor stream conditions have existed in Wilson Creek for a long time. Fish were not collected above stream mile 1.5 because frequent low dissolved oxygen concentrations, ammonia, and sludge banks were present during this investigation.

Sulfides which sometimes accompany poor stream conditions are toxic to fish in very low concentrations (1,5). Faint, rotten-egg odors of hydrogen sulfide were detected at times on Wilson Creek; but hydrogen sulfide was not found in field or laboratory samples. To confirm the presence of toxic sulfides in Wilson Creek, a technique used by Keup and Stewart (3) was applied to an area of Wilson Creek where odor problems and fish kills have occurred in the past.

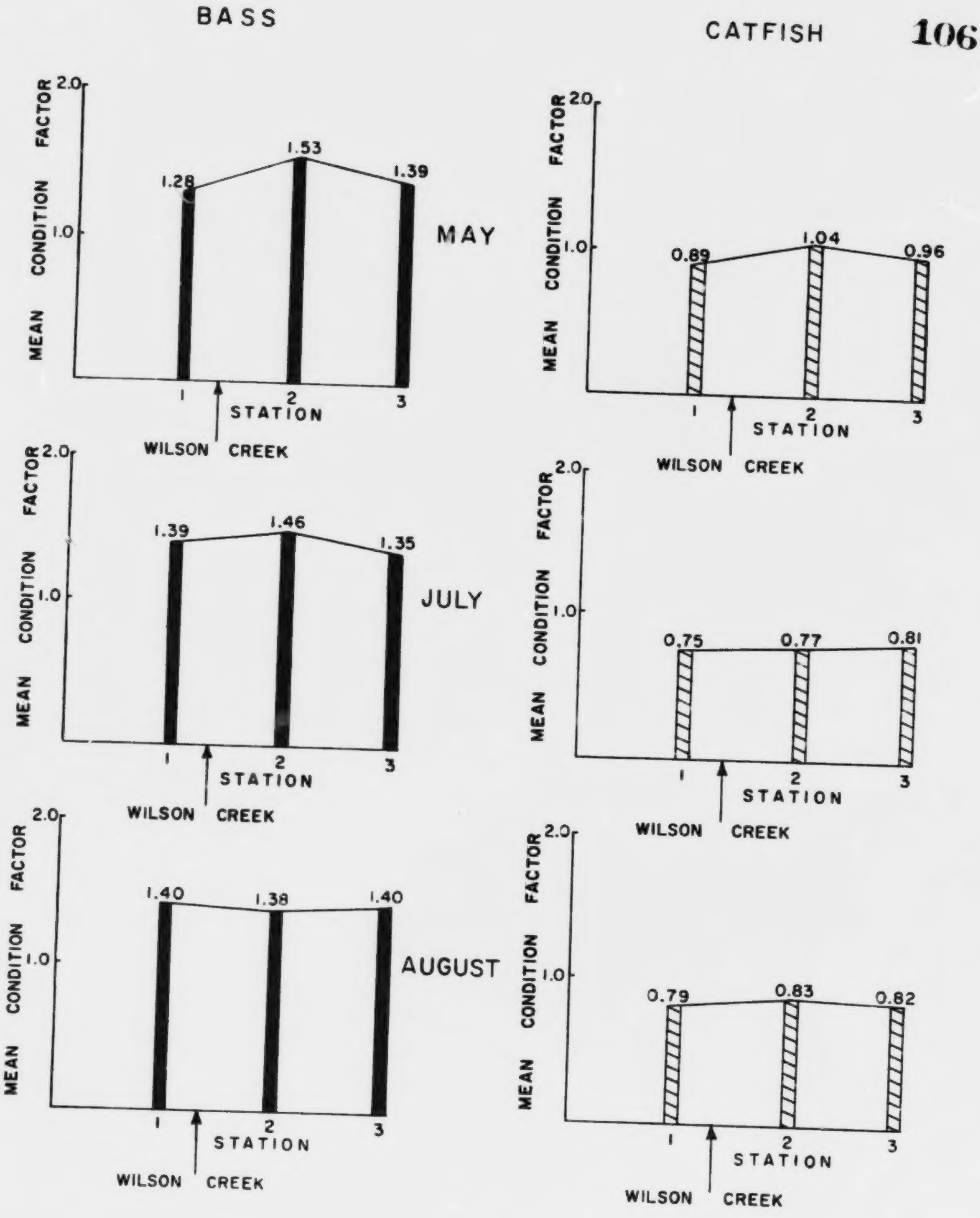


FIGURE 5 - CONDITION FACTOR OF JAMES RIVER FISH COLLECTED IN MAY, JULY AND AUGUST, 1968.

Figure 6 illustrates the results of placing silver dimes in Wilson Creek. Sulfides react chemically with the silver to form black silver sulfide. The dimes were placed on the stream bottom for a period of two weeks. Dimes which were covered by a thin blanket of sludge turned black. The change in color of these dimes from silver to black is a positive test for the presence of sulfides, but the corrosion is accumulative; therefore, the concentration at any given time is unknown.

There were eleven species of fish collected on Wilson Creek below mile 1.5. Four[1] of these eleven species were game fish but the game fish comprised only a small amount of total fish collected here (Table 4). Rough fish tend to be more predominant in degraded waters (3). The abundance of rough fish at Station 5 indicated that improved, but degraded, conditions existed in the lower reaches of Wilson Creek.

Terrell Creek contained 13 species of fish (Figure 3). This creek is entirely spring-fed, so the water temperature rarely exceeds 65°F. Thus, this stream does not harbor a typical warm water fish population. For this reason, Terrell Creek was not included in Figure 4.

Approximately 98 percent of the 13 species collected in Terrell Creek were forage fish which preferred the shallow riffle habitat and colder water indicative of this stream (Table 4). The large number of forage fish at Stations 4 and 5 on Wilson Creek (Figure 4)

[1] Includes Rainbow trout

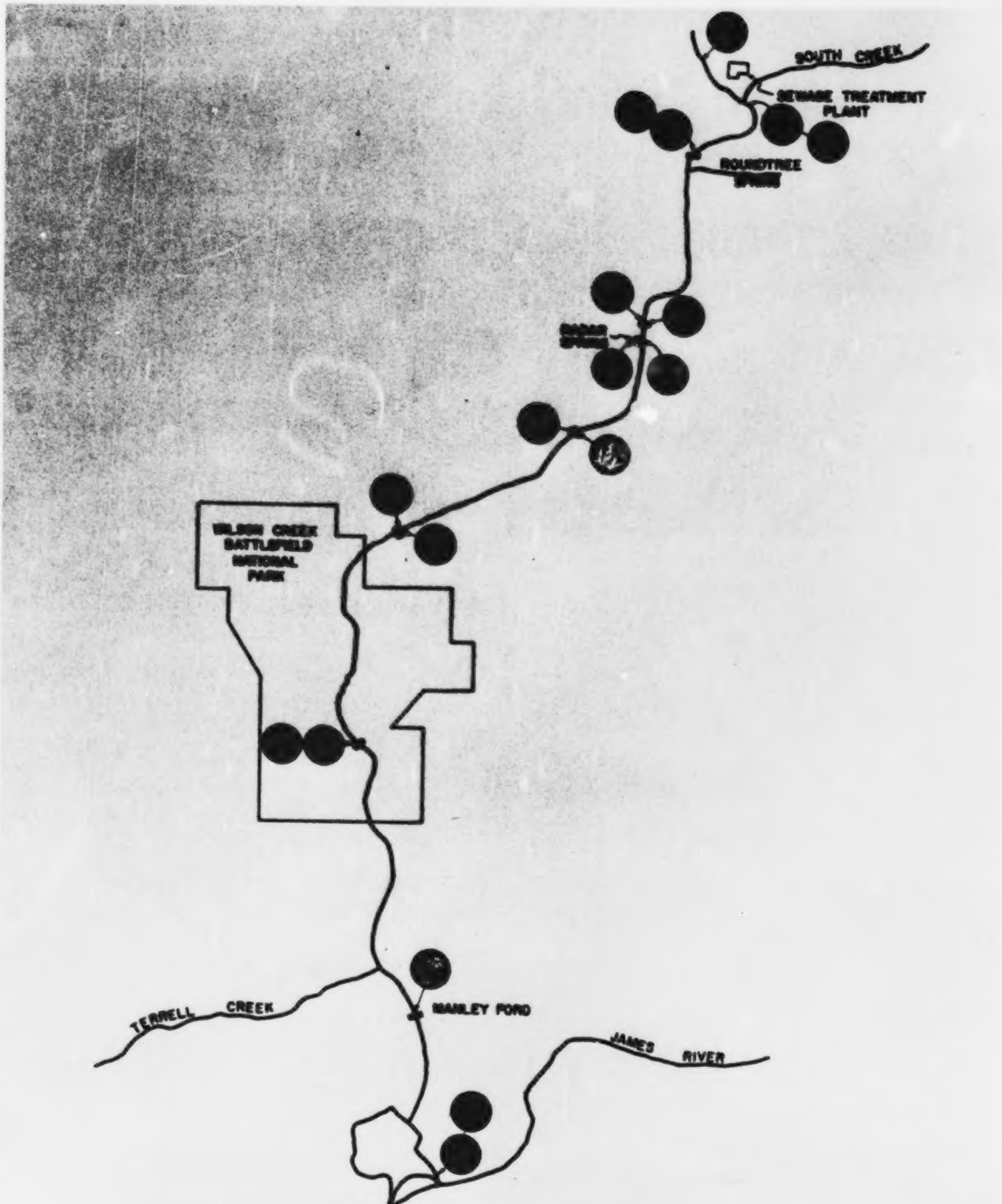

SOUTH CREEK
SEWAGE TREATMENT PLANT
ROUNDTREE SPRING
SPRING
WILSON CREEK BATTLEFIELD NATIONAL PARK
TERRELL CREEK
MANLEY FORD
JAMES RIVER

FIGURE 6 - CORROSION OF DIMES SUBMERGED FOR TWO WEEKS IN WILSON CREEK, MISSOURI, 1968.

reflects the role Terrell Creek played in improving stream conditions for the last mile of Wilson Creek.

Stream conditions in Terrell Creek, except for flow, remained stable throughout the investigation; and no pollution was evident in this stream.

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Table 4 Summary of Fish Captured by Electrofishing in Terrell Creek, Missouri - May 1968

Table 1

A List of Common Names* of Fish
Collected During
the James River Investigation

GAME	FORAGE	ROUGH
Largemouth bass	Gizzard shad	Carp
Smallmouth bass	Banded sculpin	Longnose gar
Spotted bass	Stoneroller	Northern redhorse
Rock bass	Ozark minnow	Golden redhorse
Longear sunfish	Common shiner	Northern hogsucker
Bluegill	Blackspotted topminnow	White sucker
White crappie	Logperch	Plains carpsucker
Black crappie	Silver chub	Highfin carpsucker
White bass	Whitetail shiner	Quillback
Green sunfish	Bleeding shiner	Bigmouth buffalo
Channel catfish	Hornyhead chub	
Flathead catfish	Mottled sculpin	
Black bullhead	Orangethroat darter	
Rainbow trout	Northern studfish	
	Southern redbelly dace	
	Brindled madtom	
	Creek chub	
	Slender madtom	
	Mooneye	

---

* Taken from *A List of Common and Scientific Names of Fish from the United States and Canada*, American Fisheries Society, Special Publication No. 2, 1960.

Table 2
Summary of Fish Captured by Electrofishing in James River, Missouri
May - August 1968

Station Number	1				2				3			
Date	May	June	July	Aug.	May	June	July	Aug.	May	June	July	Aug.
Electrofishing Hours	4.75	2.33	1.50	2.75	3.83	2.63	1.72	2.83	3.15	1.06	1.42	2.16
Game												
Largemouth bass	15	6	2	12	28	15	11	27	16	6	5	23
Smallmouth bass	-	-	-	-	-	-	-	-	4	-	-	-
Spotted bass	70	9	18	38	18	9	5	13	36	8	9	21
Rock bass	5	3	4	6	-	-	-	-	1	-	1	1
Longear sunfish	108	8	38	53	17	1	15	11	43	10	10	30
Bluegill	19	4	8	28	48	14	18	57	32	10	14	56
White crappie	-	1	-	1	-	-	1	2	2	-	1	7
Black crappie	-	-	-	2	-	-	1	-	-	-	2	-
White bass	1	-	-	-	-	-	-	-	1	-	-	-
Green sunfish	23	1	4	1	3	-	13	7	6	1	11	13
Channel catfish	51	14	2	33	52	17	23	36	44	4	19	47
Flathead catfish	3	-	-	-	-	-	-	-	-	-	-	-
Black bullhead	-	-	-	-	-	-	-	-	-	1	1	-
Rainbow trout	-	-	-	-	1	-	1	1	1	-	-	-
Total	295	46	74	174	167	56	88	154	186	40	73	198
Grand Total	589				465				497			
Forage												
Gizzard shad	403	134	120	177	235	29	222	284	175	20	231	305
Banded sculpin	5	-	-	-	-	-	-	-	-	-	-	-
Stoneroller	12	3	-	5	26	1	-	-	5	-	-	-
Ozark minnow	9	-	-	-	3	-	-	-	9	-	-	-
Common shiner	3	1	-	1	4	1	-	-	5	4	6	-
Blackspotted topminnow	3	-	-	-	-	-	-	-	-	-	-	-
Logperch	1	-	-	3	-	-	3	-	1	-	1	-
Silver chub	-	-	-	-	2	-	-	-	2	-	-	-
Whitetail shiner	1	-	-	-	-	-	-	-	1	-	-	-
Bleeding shiner	1	-	-	-	-	-	-	-	1	-	-	-
Mooneye	-	-	-	1	-	-	-	-	-	-	-	-
Orangethroat darter	1	-	-	-	-	1	-	-	1	-	-	-
Northern studfish	1	-	-	-	-	-	-	-	-	-	-	-
Brindled madtom	1	-	-	-	-	-	-	-	-	-	-	-
Slender madtom	3	-	-	-	-	-	-	-	-	-	-	-
Total	444	138	120	187	270	32	225	284	200	24	238	305
Grand Total	889				811				767			
Rough												
Carp	116	23	33	114	153	93	56	93	111	27	33	66
Plains carpsucker	4	-	1	-	1	2	-	-	5	-	-	-
Quillback	5	-	-	-	-	-	-	-	-	-	-	-
Longnose gar	6	11	-	-	1	3	-	-	1	1	-	-
Northern redhorse	70	36	36	106	255	85	70	139	116	23	31	106
Highfin carpsucker	8	18	5	18	2	1	-	-	2	-	-	-
Northern hogsucker	12	4	7	17	6	1	1	-	3	-	7	6
Golden redhorse	4	-	-	-	-	-	-	-	-	-	-	-
White sucker	-	-	-	-	1	-	-	-	-	-	-	-
Bigmouth buffalo	-	-	-	-	-	-	-	-	1	-	1	-
Total	225	92	82	255	419	185	127	232	239	51	72	178
Grand Total	654				963				540			

Table 3
Summary of Fish Captured by Electrofishing in Wilson Creek, Missouri
May - June 1968

Station Number	4		5		6		7	
Date	May	June	May	June	May	June	May	June
Electrofishing Hours	0.30	0.30	0.42	0.33	0.5	0.17	0.1	0.1
GAME								
Largemouth bass	3	-	2	-	-	-	-	-
Bluegill	1	8	10	-	No Fish	No Fish	No Fish	No Fish
Rainbow trout	2	-	-	-				
Channel catfish	-	1	-	-	-	-	-	-
Total	6	9	12	-	-	-	-	-
FORAGE								
Gizzard shad	2	69	55	-	-	-	-	-
Stoneroller	1	-	12	-	No Fish	No Fish	No Fish	No Fish
Ozark minnow	-	-	4	-				
Common shiner	-	2	47	-	-	-	-	-
Total	3	71	118	-	-	-	-	-
ROUGH								
Carp	7	13	85	44	No Fish	No Fish	No Fish	No Fish
Northern redhorse	-	-	1	-				
White sucker	1	-	-	-	-	-	-	-
Total	8	13	86	44	-	-	-	-
Grand Total	17	93	216	44				

Table 4

Summary of Fish Captured by Electrofishing in Terrell Creek, Missouri

May 1968

Date	May
Electrofishing Hours	0.33
GAME	
Largemouth bass	1
Bluegill	2
Total	3
FORAGE	
Stoneroller	110
Ozark minnow	159
Common shiner	6
Hornyhead chub	1
Mottled sculpin	2
Orangethroat darter	6
Southern redbelly dace	173
Creek chub	15
Total	472
ROUGH	
Northern hogsucker	2
White sucker	5
Total	7
Grand Total	482

APPENDIX D

GROUNDWATER INVESTIGATION

James River-Wilson Creek Study
Springfield, Missouri

APPENDIX D

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Figure 18 Location of Test Pits, Resistivity and Seismic Profiles, Springfield Southwest Sewage Treatment Lagoon Site

INTRODUCTION

As previously discussed in the main report, water quality problems in the Wilson Creek basin are complicated by the karst topography of the area. Large quantities of surface water and significant volumes of waste water enter the upper groundwater aquifers through numerous sinkholes, some of which are in the bed of Wilson Creek. This water reappears as surface water further downstream, primarily at Rader Spring, often in a degraded condition. The quality of Rader Spring, due to its size, is a primary determinant of the quality of lower Wilson Creek, and to a lesser extent, a portion of the James River. Therefore, as an integral part of the James River-Wilson Creek Study, it was necessary to define the geological structure of the area, the location and extent of the underground drainage system, the quality of the groundwater aquifer, and its hydrological characteristics and relationships with surface flow.

CONCLUSIONS

A study of karst conditions, caves, springs, shallow groundwater and possible pollution sources in the watershed of Wilson and South Creeks and a segment of the James River indicates no major sources of contamination. However, there is contamination of the groundwater from the sinkhole on the south bank of Wilson Creek, adjacent to the Springfield Southwest Sewage Treatment Plant outfall,to Rader Spring. Water and plant effluent are lost underground from Wilson Creek at this point (4). This conclusion does not refer to stormwater runoff from the City of Springfield or clandestine local garbage dumps, but is limited to the geologic aspect of possible pollutant sources from urban and rural areas with emphasis on the transport of pollutants through a shallow underground system of limestone. This subsurface system underlies the entire project area. Surface water from streams and storm runoff enters this system at higher elevations through caves, sinkholes, faults, connecting vertical joints and horizontal bedding planes and moves by gravity flow down to lower elevations. A more dense, noncavernous limestone under this top layer restricts vertical movement into the deeper formations. During heavy storm runoff and high streamflow the hydrokinetic pressure in the underground system builds up causing some sinkholes at low elevations to discharge rather than accept water.

Additional conclusions based on specific geohydrological characteristics of the study area are:

1. A structural high in the Reeds Spring formation is blocking the southwestward movement of shallow groundwater so that it surfaces as springs and streamflow recharge in the lower segment of Wilson Creek and along the James River (Figure 17).
2. The effluent lost into cavernous limestone at the Springfield Southwest Sewage Treatment Plant does not accumulate in the groundwater depression of that area as originally suspected in earlier reports (4,9,10). No evidence has been found in this study to support the contention that underground drainageways in the project area contain large reservoir chambers in which floodwaters might be stored following heavy precipitation.
3. Rader Spring is the master spring in the Wilson Creek basin, receiving flow from several confirming directions and from several hypothetical directions (Figure 15).
4. The groundwater quality surveys indicated no shallow groundwater pollution in the Wilson Creek watershed, other than that associated with the Springfield Southwest Sewage Treatment Plant and Rader Spring.
5. The proposed flow augmentation lake on Wilson Creek (8) is in a poor location geologically since it is underlain by active sinkholes and is in a groundwater depression (Figure 14).

6. The proposed tertiary and bypass treatment lagoon (1) adjacent to Wilson Creek in NE NE Sec. 7, T. 28N., R. 22W should have its outfall downstream (Figure 14). Water loss occurs on Wilson Creek adjacent to the Springfield Southwest Sewage Treatment Plant outfall. The outfall is at a right angle to the stream and is believed to have enlarged a sinkhole on the south bank of the stream. The outfall of the tertiary and bypass treatment lagoon could create a similar problem. Locating the outfall parallel and downstream at Rader Spring would lessen the chances of this occurring again and having dilution of the plant effluent.
7. A complete hydrologic study of this area would be necessary before a true evaluation of the proposed flow augmentation lakes could be made. This would also be necessary before deep aquifer pollution could be ascertained.

The significant geologic features that have a major role in this conclusion are: 1) cavernous limestone (Burlington-Keokuk) of Mississippian age; 2) dense, relatively non-cavernous, cherty limestone (Reeds Spring formation) of Mississippian age; 3) karst (sinkhole) areas in portions of South Creek and Wilson Creek and in the uplands west of Wilson Creek and south of James River; 4) a northwest-trending fault and parallel folds extending from the area of Nixa northwestward toward the Pond Creek watershed; and 5) abundant shallow groundwater within 25 to 100 feet of the surface.

DESCRIPTION OF THE PROJECT

Location - Geographic

The groundwater study area covered essentially the Brookline, Nixa, Republic and Springfield 7 1/2-minute quadrangle maps of Missouri as published by the U. S. Geological Survey. This included the south-central area of Greene County and north-central area of Christian County, Missouri.

The northeast quadrangle is Springfield, Missouri, the county seat of Greene County. Elevations within the city range from 1180 to 1380 feet above sea level. Springfield straddles the southern boundary of the Missouri River Basin to the north and the northern boundary of the White River Basin to the south.

Drainage of the southeastern parts of Springfield is into branches of the James River, a tributary of the White River. This area is on the Nixa quadrangle, the southeast quadrangle of the project. The James River flows to the west along the northern edge of the quadrangle.

The western, central and eastern sides of Springfield drain into Fassnight and Jordon Creeks, tributaries of Wilson Creek. Wilson Creek flows generally south from the southwestern side of Springfield between the Brookline quadrangle in the northwest and the Springfield quadrangle. Drainage in south Springfield is into South Creek which flows west and southwest and joins Wilson Creek at the Springfield Southwest Sewage Treatment Plant.

The southwest quadrangle, Republic, contains the confluence of Wilson Creek and the James River. McElhaney Branch, Shuyler Creek and Terrell Creek join Wilson Creek in this quadrangle.

The groundwater drainage system was studied and mapped in these four quadrangles to ascertain what effect it had on the surface hydrology of Wilson Creek.

Location - Geologic

The City of Springfield, Missouri, and the study area to the southwest is on the western flank of the Ozark Uplift (Figure 1). Gently fluctuating limestone of Mississippian age is present at or near the surface in most of Greene and Christian Counties (Figure 2). The topsoil and unconsolidated material cover this strata by variable degrees of thickness. The regional dip or inclination of the strata is to the west-southwest. The northeast-southeast boundaries of the Mississippian outcrop in this area form a cuesta-like feature, a ridge with a steep face on one side and gentle slope on the other, known as the Eureka Springs Escarpment (Figure 1). The "Ozarks" are to the east and the "Western Plains" are to the west of this escarpment (2).

The Mississippian around Greene County ranges in thickness from 200 to 300 feet. The Compton and Northview formations comprise the Kinderhookian Series and the Osagean Series includes the Pierson, Reeds Spring, Grand Falls, and Burlington-Keokuk formations (Figure 3). The Compton is a fine crystalline, crinoidal limestone, and Northview consists of brown, buff, occasionally blue siltstone, and blue or bluish-green shale. The Osagean Series is characteristically limestone, which is very cherty, crinoidal, coarsely crystalline and fossiliferous; and they cannot be easily distinguished from each other. The Burlington limestone and the overlying Keokuk limestone are even more difficult to separate than the others, as the boundary between the two formations is obscure (5).

In most reports the two are combined as one unit and their total thickness is recorded. However, the thickness of the Burlington formation is fairly uniform throughout the state--seldom more than 100 feet.

Project Work Plan

Structural Mapping

Since the rock formations in the Mississippian system below the top soil around Springfield are limestone, with one exception, it was difficult to determine the subsurface structural contours of the aquifer without this "marker bed" in this series of geologic time. Fortunately, the Northview formation exists as blue siltstone or bluish-green shale (5) and is easily distinguished from limestone.

A very complete file of existing sample logs of all wells drilled in the State of Missouri is located in the office of the Missouri Geological Survey and Water Resources, Rolla, Missouri. The record revealed that sufficient wells were drilled through the Northview formation in Greene and Christian Counties to give structural control.

Refraction seismograph and electrical resistivity studies also were made in conjunction with the contour mapping in locating faulting and structural change. With these data, structural contour maps of the Northview-Pierson contact and the base of the Burlington were constructed by the Missouri Geological Survey (Figures 12 & 13).

Drainage System

Surface Area of Watershed Map - The U. S. Geological Survey 7 1/2' quadrangle maps of the area were used for this mapping (Figure 14).

Internal Drainage Map - The rock formation exposed in this study area consists of deeply weathered limestone and dolomite. Nearly vertical joints present in the bedrock exposures and bedding planes influence the underground movement of water (11). A large percentage of the annual precipitation percolates through permeable residual material and detrital-filled joints and bedding planes into an interior drainage system and emerges through springs. The primary need for the geophysical studies, dye tracing, cave and surface reconnaissance was to ascertain the full impact this subsurface drainage system has on the hydrology of the Wilson Creek watershed. From this information the suggested path of water movement and an internal drainage map was drawn (Figure 15).

Groundwater Level Map - Data from the well log library at the Missouri Geological Survey, water level records of observation wells within the study area, and field observations of water levels in the remaining wells and sinkholes within the study area were used to construct this map (Figure 16).

Groundwater Quality Survey - Two groundwater quality surveys of the project area were conducted. The field tests included temperature, pH, conductivity and total sulphide. The laboratory analyzed each well sample for organic nitrogen, ammonia, nitrites, nitrates, sulfates, total phosphate and total organic carbon.

A lengthy and detailed list of water wells in four categories (based on depth and casing) was furnished for the survey by the Missouri Geological Survey and the U. S. Geological Survey. From the above mentioned well log files, information concerning well location, code number, depth, casing point, water level, date drilled, yield test and formation depths were punched on computer cards and processed into four categories. A fifth category was added from the field surveys. They are as follows:

Well Coded Prefix

0 - No casing record available.

1 - Mississippi (Adequate) - Well was drilled to the Mississippi System and cased to or below the top of the Mississippi.

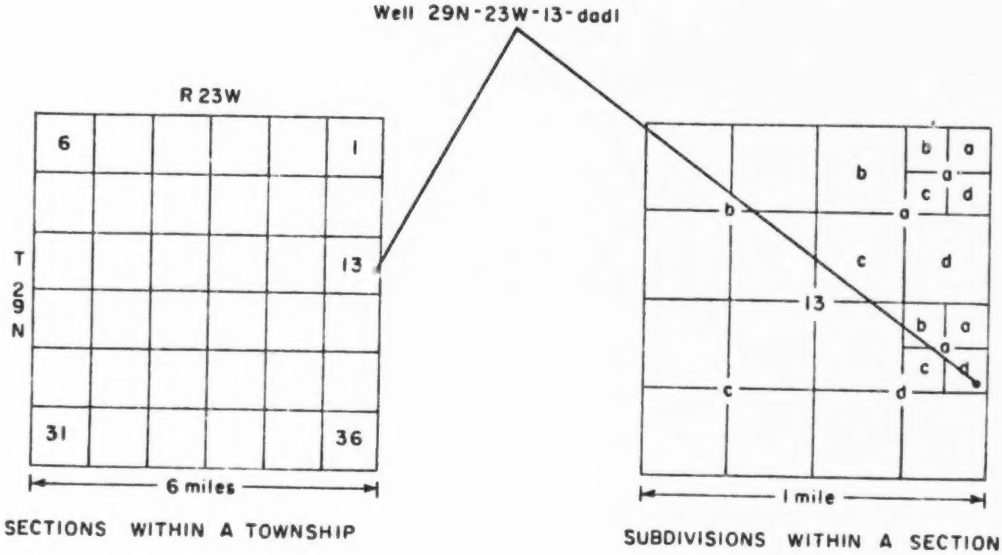
2 - Ordivician (Inadequate) - Well was drilled through the Mississippi System into the Ordivician System, or deeper and sufficient casing was not run to exclude water from other zones.

3 - Ordivician (Adequate) - Well drilled to Ordivician System and sufficient casing run to, or through, the top of the formation.

4 - No well records available. Wells located by field survey. No well sampled deeper than the Mississippian, although commingling could come from above.

The last category was made because of the limited number of shallow (Mississippian) wells on record. A house-to-house canvas was made in an attempt to collect one shallow well sample within each section.

The well-numbering system used was based on the Bureau of Land Management system of land subdivision. In this location system the first digit of a well number indicates the township, the second the range, and the third the section in which the well is situated. The first lower-case letter denotes the quarter section (160-acre tract), the second the quarter-quarter section (40-acre tract), and the third the quarter-quarter-quarter section (10-acre tract). Within each 10-acre tract the wells are numbered serially as indicated by the final digit of the number. Thus, in Greene County, the number 29N-23W-13-dadl indicates that the well is in the SE¼NE¼SE¼Sec. 13, T. 29N, R. 23W. (Figure 4)



SECTIONS WITHIN A TOWNSHIP

SUBDIVISIONS WITHIN A SECTION

FIGURE 4 - WELL NUMBERING SYSTEM USED IN MISSOURI

From the computer data and well location printout, and the house-to-house canvas during the sampling phase, sufficient quality data of the shallow groundwater at or near the surface streams of concern were developed to give an evaluation of overall water quality within the aquifer.

PHYSICAL AND CHEMICAL METHODS

Shallow Geophysical Surveying

Refraction Seismograph

The refraction method, using conventional reverse sounding, employs geophones spaced horizontally at a distance two to five times the depth being investigated. A shot is fired at each end of the spread and the first arrivals of the seismic waves picked up at each geophone are plotted as conventional time-distance curves. The velocity of these seismic waves varies with the layers of subsurface media encountered and can be computed from the time-distance curves and subsoil layer thicknesses can be constructed and cavernous and water solution channels can be observed (7). (See Figure 5 & 6 for examples of each.)

A small portable multichannel twelve seismograph was used. With the 12-channel seismograph one man can do the preliminary field work quite easily. He may run as many as eight forward and reverse setups in one day regardless of the length of cable.

It is advantageous to have a fair working knowledge of the subsurface condition of an area being worked. This can be obtained through field checks, outcrops and examination of recorded well logs.

Electrical Resistivity

The electrical resistivity method by the Wenner direct current-conductive electrode configuration consists of four electrodes drawn into the ground along a straight line at equal intervals. The resistivity soundings consist of expanding the electrode spacing in increments about a fixed point. A subsoil resistivity reading is taken at each increment. The depth of soil measured at each increment reading is equal to the electrode spacing. Each increment reading includes the entire soil mass from the ground surface to each particular depth increment measured. Therefore, each successive resistivity measurement includes all the soil measured in the previous reading, plus an additional new amount on the sides and bottom, resulting in a detailed electrical log of the subsoil (7). Typical resistivity soundings are illustrated in Figure 7.

The resistivity apparatus employed was a direct current model capable of shallow to moderate depth determinations. The instrument is quite light, weighing about 10 to 15 pounds fully loaded with batteries and is completely self-contained. The apparatus can be operated alone; however, two men will speed up the work considerably and three men will speed it up more. If time is not a factor, the instrument can be operated by one man.

Geophysical Surveying in the Wilson-South Creek

The use of shallow-depth portable geophysical equipment in field studies of the Wilson-South Creek study area was utilized in tracing the cavernous or water solution channels within this carbonate area.

Figure 8 is a geophysical study of a known tube cave in the project area. A point depth determination by individual, cumulative and Barnes Layer plotting was made to ascertain the depth of the cave. Although the location of the cave was known, a dual constant depth resistivity profile was made to aid in determining other possible tube caves in the area. This type of profile is conducted when the plot of the refraction seismograph (as shown in Figures 6 & 8) do not indicate the location of a cave.

Geophysical studies of the Wilson Creek and South Creek flood plains were conducted to give a general interpretation of the bedrock and groundwater characteristics of these two areas. The Wilson Creek flood plain study is the site of the proposed tertiary and bypass treatment lagoon. Interpretation of the refraction seismograph shots indicated solid uniform bedrock in portions of the flood plain and the presence of small caverns or enlarged joints and bedding plains in other areas. The resistivity survey information was insufficient to accurately determine the depths of the solution openings, but were assumed to be 20 to 30 feet below the flood plain elevation.

The seismograph profile taken across the flood plain near the mouth of South Creek indicated cavernous or loose rock zones. (See Figure 18 for the locations of these profiles.)

A major geologic fault was thought to exist in the study area and confirmed by geophysical studies. It was first discovered about one-half mile downstream of Blue Spring along the banks of the James River. The fault appeared to be in a northwest-southeast direction and physical evidence of a fault was again found at the county road bridge adjacent to the Hampton farm, north of the Wilson's Creek Battlefield National Park (Station 27). Seismic surveys across a line drawn on a map connecting the two fault locations confirmed the fault existed. The shot records indicated a brecciated zone of 25 to 40 feet in width across the surface area of the fault. A fault allowing relatively impermeable rock to butt against very permeable rock, has the potential for intercepting and diverting the groundwater flow either to the surface or to deeper aquifers.

Although these geophysical investigations in the study area pointed out the presence of solution enlarged joints or bedding planes, they were not extensive enough to fully determine the size, direction or continuity of the groundwater system. Therefore, to those unfamiliar with the results that can be obtained with geophysical surveys, the following is an explanation of Figures 9, 10 and 11, which should give some insight as to this groundwater system in a karst-limestone area.

If the cavity in the rock is shallow with little overburden, or is an enlarged joint that extends to the surface of the bedrock, the plot will be similar to that shown in Figure 9a. If the surface of the bedrock is highly pinnacled, the arrival times from the geophones will be erratic and the plot will curve similar to Figure 10a. In either case the use of the seismograph for cavern detection will be null and void, and detection will have to rely primarily on resistivity. Figure 9b illustrates a constant depth profile over a large clay-filled joint in which the joint opening extends to the top of the bedrock. Figure 10b shows a constant depth profile on highly pinnacled terrain. Figure 11 illustrates anomalies over water or clay-filled cavities in contrast to the air-filled cave in Figure 8. Notice the decrease in resistance in Figure 11.

Groundwater Dye Tracing

The Dunn method of groundwater tracing was used in this study (3). Fluorescein dye in powder form is introduced into surface water loss areas, and detectors consisting of activated charcoal in screened packets are placed in all suspected surfacing areas, such as springs, streams and reversible sinkholes. Should the dye pass through subterranean channelways and resurface at one of the monitored localities, some of the dye is adsorbed by the activated charcoal, recording the passage of the dye. Charcoal packet detectors are recovered periodically and elutriated in the laboratory using a five percent solution of KOH in ethyl alcohol. If dye has been adsorbed by the charcoal, it appears on the surface of the charcoal grains, visually, or the test can be made more sensitive by the use of ultraviolet light.

Other Physical Methods and Chemical Procedures

Field quality tests, sampling procedures, laboratory quality control and analytical methods are the same as those listed in Appendix A, Physical and Chemical Methods.

DISCUSSION

Nature of the Underground Drainage System

This geologic study was undertaken to determine groundwater movement and the effect groundwater has on the hydrology of Wilson Creek.

The contour maps of the Northview Shale-Pierson Limestone Contact and base of the Burlington were useful to determine that the Reeds Spring limestone was blocking the shallow groundwater movement. The Reeds Spring formation is a dense and therefore noncavernous limestone. The fact that it occurs abnormally high in this area is the reason for Rader Sink, Rader Spring, other unnamed springs, and streamflow recharge in Lower Wilson Creek (Figure 17).

When the capacity of subterranean drainageways is exceeded, as following heavy rainfall, Rader resurgence-sink, SE¼, NE¼, NW¼ Sec. 18, T. 28N., R. 22W., discharges excess water; during drier periods the flow is reversed in the resurgence-sink, and water from Wilson Creek flows into the depression and thence to Rader Spring. Other resurgence-sinks in the vicinity of the Springfield Southwest Sewage Treatment Plant reverse in the same manner when the capacity of underground drainageways is exceeded. Extremely heavy or prolonged rainfall is necessary before water flows from the resurgence-sink immediately south of the sludge drying beds at the Springfield Southwest Sewage Treatment Plant.

The location of the faults and folds in the area were determined from contour maps as well as the geophysical surveys.

Studies made in 1966 (9,10) indicated that large reservoirs might exist underground where waste materials could settle out and be discharged back to the stream when high flows occur.

There is a tendency in study of areas such as the Wilson Creek Project where underground drainage is of importance, to assume that the entire subsurface area is honeycombed by ramifying networks of caverns and fractures. This idea cannot be supported by the data obtained during this study. Tracing of the underground streams in the Wilson Creek drainage basin and adjacent areas indicates that subterranean streams have developed at shallow depth in the surface aquifers of the region, and have produced underground drainage systems similar in orientation to surface drainage systems. Some of the same factors which determine the course of surface streams, such as fractures, faults, jointing in the bedrock, and structure (slope) of the bedrock also appear to affect the orientation of underground drainage. An example of this relationship between surface and subsurface drainage is in the tributary to South Creek with headwaters in Sec. 1 and intersection with South Creek in Sec. 5, T. 28N., R. 22W.

This tributary is strikingly aligned east-west, and along its entire course are sinkholes in the valley floor. Water tracing experiments have shown that water movement parallels surface drainage and resurges in Rader Spring. Water loss zones in South Creek and upper Wilson Creek lend support to the hypothesis that subsurface drainage routes approximate surface drainage routes, and are governed by the same structural conditions that influence surface drainage.

Examination of segments of the underground drainage systems through known caves in the area shed much light on the nature of the underground conduits which carry subsurface groundwater flow. Without exception, these caves show relatively small passageways, frequently constricted by low crawlways and occasionally by ponded water and frequently terminated by siphons or roof collapse. Most of these passages examined in this study have had partial fills of chert and limestone cobbles, boulders and gravel, and frequently the cave systems contain sizeable deposits of dark, silty clay and appear to be in a formative stage of development. No evidence was found in this study to support the contention that the underground drainageways in the Wilson Creek project area contain large reservoir chambers in which floodwaters or polluted waters might be stored following heavy precipitation. However, the storage capacity of the solution channels is still significant due to their length. Growth of the subterranean drainage networks is probably contemporaneous with the development of surface drainage patterns, and because the subsurface drainageways are still in a formative stage, large chambers and sizeable passages have not yet developed in the lower reaches of Wilson Creek valley. However, the presence of large sinkholes in the upland regions of the project area suggests that cavern systems may exist in the area which are older than those along the valley of Wilson Creek, and the large sinkholes suggest collapse of cavern roofs in areas where the underground cavities may have grown considerably larger than any now existing along the valley of Wilson Creek. In this respect, it must be remembered that the

Burlington-Keokuk limestone along Wilson Creek valley is quite thin, whereas beneath the uplands of the project area the thickness of the Burlington-Keokuk may exceed 200 feet. Because only very short segments of the subterranean drainageways can be examined through the known caves of the project area, it is assumed that the greater percentage of the subsurface drainage network is inaccessible to man. Nevertheless, the rapid travel of tracers introduced into underground streams in the project area suggests that the underground channelways are relatively unconstricted and are not filled by large deposits of clay, silt or gravel, such as would obstruct the flow of groundwater. Further evidence strengthening this view lies in the fact that fluorescein dye is adsorbed by clay, will not pass through extensive blockages of sediment, and is a poor groundwater tracer in highly turbid waters.

The behavior of the various resurgence-sinks thus far discovered along Wilson Creek indicates that the underground channelways carrying groundwater beneath the valley of Wilson Creek and its tributaries are incapable of carrying excessive amounts of stormwater runoff. The resurgence-sinks act as "overflow valves" for the underground drainage system. The Rader resurgence-sink accepts water in periods of low flow of Rader Spring and Wilson Creek, and discharges water in periods of high flow. The other known resurgences along Wilson Creek do not readily accept water because their outlets are slightly above the normal level of Wilson Creek. However, after heavy rainfall the resurgences operate in sequence following the reversal of flow in Rader resurgence-sink. Following extremely heavy rainfall, all resurgences and even Tube Cave, which is normally a groundwater intake, have been known to discharge groundwater. Also, the sinkhole in the bed of Wilson Creek has been observed going both ways.

Using the four quadrangles of the project area as a base map, an internal drainage map was plotted from the topographic base (Figure 15). Probable drainage areas of each sinkhole were outlined, and coalescing drainage areas of adjacent sinkholes were shown as contiguous areas. The completed internal drainage map shows major areas in all four quadrangles in which all surface water is drained internally through sinkholes. Of most concern to the Wilson Creek Project are the internally drained areas in the southern half of the Springfield quadrangle and the eastern half of the Brookline quadrangle. The large internally drained area in the northwest corner of the Springfield quadrangle and northeast corner of the Springfield quadrangle and northeast corner of the Brookline quadrangle probably emerges north of Springfield, and therefore, is of no consequence to the project. In like manner, the large internally drained areas in the Nixa quadrangle and the Republic quadrangle are somewhat outside the major project area, except for the drainage into Blue Spring. The subsurface drainage eastward from Republic is significant, if the flow is very large. Internally drained areas in the Wilson Creek basin approach 10 square miles in area.

Analysis of the internal drainage map in comparison with the structure contour map and the groundwater level map suggest that most subsurface groundwater movement in the project area is through solution channels in the shallow surface aquifer, the Burlington Limestone. Some groundwater transfer may occur in the Reeds Spring formation, but the Reeds Spring frequently is a barrier to vertical groundwater movement. No direct evidence of water loss into deeper aquifers can be interred from data obtained thus far. (See page 24, para. 6)

Directions of movement of groundwater in the Wilson Creek project area were determined by groundwater tracing utilizing fluorescein dye in the Dunn method. Results of the groundwater tracing indicate the following lines of movement:

1. Water lost through a sinkhole in South Creek 1/4 mile northeast of the sewage treatment plant moves through subsurface conduits in the Burlington Limestone to Rader Spring.
2. A sizeable underground stream flowing at a depth of 25 feet below the level of Wilson Creek in NW¼, NW¼, Sec. 32, T. 29N., R. 22W., two miles north of the sewage treatment plant, flows through subterranean conduits in the Burlington Limestone to Rader Spring.
3. Water loss from the tributary of South Creek with its mouth in SW¼ Sec. 5, T. 28N., R. 22W., and headwaters in Sec. 1, T. 28N., R. 22W., flows through subterranean conduits in the Burlington Limestone to Rader Spring.
4. Surface water loss in South Creek in the SW¼ Sec. 12,

T. 28N., R. 22W., flows through subterranean conduits in the Burlington Limestone toward Ward Spring in the SE¼ Sec. 14, T. 28N., R. 22W.

5. Rainfall falling upon internally drained areas lying west of Wilson Creek and north of Rader Spring, as shown on the internal drainage map, also flows to Rader Spring. The only water tracing tests attempted west of Wilson Creek were in the headwaters of Shuyler Creek. Subsurface drainage here is aligned with the south-eastward surface drainage toward Wilson Creek.
6. Insufficient detailed hydrologic and meteorologic data are available to determine whether subsurface water is being lost to deep aquifers in the Wilson Creek area.
7. Subsurface groundwater movement in the Springfield quadrangle (NE¼ project area) is generally to the southwest, and is assumed to join the groundwater of numbers 1, 2 and 3 above.
8. Subsurface groundwater movement in the Nixa quadrangle (SE¼ project area) is to the northwest, rising at Blue Spring.

Perennial Groundwater Level Map and Structure Contour Map

Analysis of the perennial groundwater level map shows a broad groundwater high approximately beneath Springfield, with the perennial groundwater level sloping toward the southwest (Figure 16). Groundwater moving in a generally southerly direction from groundwater highs, in the upper Brookline and Springfield quadrangles, is passing at shallow depth beneath the land surface in the vicinity of the Springfield Southwest Sewage Treatment Plant, and resurging at Rader Spring, which has an elevation of 1,110 feet at a point where the structure contour map shows the base of the Burlington-Keokuk at approximately 1,100 feet.

Thus, it appears that the sewage treatment plant is situated approximately atop the major subsurface groundwater conduits in the Wilson Creek project area.

The perennial groundwater level map is based on information gathered from written well logs, discussions with well drillers and home owners, spring and cave data, and physical characteristics of major stream valleys. The map does not represent groundwater trends in an isotropic medium. It represents groundwater moving in subsurface streams through sinuous caverns and crevices developed at various levels in the massively bedded Burlington-Keokuk Limestone. Therefore, the slope of the water table is based upon an average number of similar elevations in a given area. Abnormally high or low elevations in the same area are ignored.

storms the capacity of the sinkhole is exceeded and water backs up and floods the residential area surrounding the sinkhole.

Ordinarily the subdivision sinkhole is dry, but after rainfall stormwater discharges into the sinkhole. Five pounds of fluorescein dye were introduced into the subdivision sinkhole at 12:30 p.m., October 15, 1968, following approximately two inches of rainfall during the preceding 24 hours. Rain was falling at the time, and an estimated 3 to 4 cfs of stormwater drainage was entering the sinkhole with no ponding. The water was slightly turbid. Rader Spring and Rader resurgence-sink were monitored at approximately 1 p.m. on November 15, 1968; and at that time Rader Spring was flowing vigorously; Wilson Creek was in flood; and the resurgence sink had had a high discharge into Wilson Creek. Rader Spring was only slightly turbid, and the water level was approximately six inches above the top of the staff guage at the spring orifice. Rader resurgence-sink had high water within one inch of overtopping the staff guage.

The first detectors were recovered from Rader Spring at 12:30 p.m., November 18, 1968, and reacted strongly positive. The charcoal packet was recovered from Rader resurgence-sink at approximately the same time and it also reacted strongly positive. Approximately 72 hours elapsed from time of injection in Subdivision Sink and time of positive reaction of the charcoal packets from Rader Spring and Rader resurgence-sink. However, this is not a measure of travel time, because the dye was not detected visually in the spring; and therefore, the dye had passed the spring orifice at some time prior to recovery of the first monitor. The straight-line distance between Subdivision Sink and Rader Spring is approximately five miles. As might be expected, travel time appears to be shorter in periods of high groundwater discharge than it is during low flow.

Water Tracing: Pfaff Cave-Rader Spring

Pfaff Cave has a pit-type entrance in a sinkhole in NE¼, NW¼, NW¼, NW¼ Sec. 32, T. 29N., R. 22W., approximately two miles north of the sewage treatment plant. The cave has a total depth of approximately 60 feet, with an entrance elevation of 1200 feet. Wilson Creek flows as a perennial stream approximately 700 feet west of the sinkhole entrance to Pfaff Cave. Elevation of the stream bed at this point is approximately 1165 feet. Pfaff Cave carries a sizeable stream in its lower reaches which flows a minimum of 25 feet below the bed of nearby Wilson Creek.

Four pounds of fluorescein dye were injected in the stream in Pfaff Cave on November 22 at approximately 12:30 p.m. Flow of the stream was estimated to be 2-4 cfs, with the lower 10 feet of the cave flooded. The stream was extremely clear and vigorous, and the only impedance to the flow through the cave appeared to be constriction in the solution channels. Detectors were placed in Rader Spring and Rader resurgence-sink, and when the dye monitors were first tested on November 25 at 5 p.m., they tested strongly positive. No dye was detected visually in the spring, indicating that the entire injection had passed both the spring outlet and Rader resurgence-sink at some time earlier in the 77-hour period from Friday noon to Monday at 5 p.m.

At the time of recovery, stage at Rader Spring was 1.75 and at Rader resurgence-sink, 1.08. At 5 p.m., November 25, 1968, Rader resurgence-sink appeared to be approximately at equilibrium with no detectable current either into or out of the sink.

Water Tracing: Parkcrest Subdivision Sinkhole-Ward Spring

There is a large swallow hole opposite the Parkcrest Shopping Center, in the SW¼ Sec. 12, T. 28N., R. 22W., which takes water from a drainage area of approximately 400 acres. The swallow hole is in a beheaded valley and a small spring immediately upstream from the swallow hole provides a permanent, though small, supply of water. One pound of fluorescein dye injected at the Parkcrest swallow hole required a minimum of three days to travel to Ward Spring, approximately one mile south of the Parkcrest swallow hole, in SE¼, SE¼ Sec. 14, T. 28N., R. 22W. The dye was injected during a period of relatively low flow, and frequent sampling was conducted for 2 1/2 days, with negative results. Detectors were not again recovered from Ward Spring until one week later, after a period of heavy rainfall. The detectors gave a strong positive reaction, indicating that dye had passed the detecting station during the interval following the 2 1/2 days of sampling.

Groundwater Quality Surveys

The two groundwater quality surveys conducted gave no indication of any major shallow groundwater pollution other than that of Rader Spring by the entrance of sewage into the groundwater. Localized pollution of shallow groundwater is a problem in some areas. The first survey was made May 22-23, 1968. From well information furnished by the U. S. Geological Survey, an attempt was made to locate all shallow wells still in operation. Water from 25 wells was sampled and analyzed within a 90-square mile area. These data are listed in Table 1. Since the USGS information did not contain enough wells to obtain at least one sample per section, it was decided to canvas every house within each section in an attempt to locate shallow wells that were only producing from the Mississippian. Water samples from 57 wells were obtained in this survey conducted June 4-6, 1968, in an 80-square mile area. These data are listed in Table 2.

Unsewered suburban developments do not appear to be polluting the groundwater. However, this is a very real danger due to the nature of the soil. Much of this area, with the exception of the region north of Highway M, is not intensely developed. Information obtained from the Greene County Health Department indicated that wells in the south Springfield area do not show bacterial contamination. Land and air reconnaissance revealed eight sewage lagoons and no large confined feedlots in the area.

Geological Aspects of Flow Regulation Structures

Wilson Creek

Although a flow augmentation dam on Wilson Creek (8) would increase minimum flows, additional geologic studies would be necessary to determine whether a dam would be feasible. Geophysical surveys, core drilling and pressure testing will be necessary to determine if the bedrock is structurally sound; and if any large cavities or hidden sinkholes exist. The internal drainage-surface relationship would have to be understood, also. A sizeable underground stream is known to flow as deep as 25 feet beneath the bed of upper Wilson Creek, as shown by the underground stream in Pfaff Cave, NW¼, NW¼ Sec. 32, T. 29N., R. 22W. The flow of this underground stream may be derived from several sources, including seepage losses from the bed of Wilson Creek upstream from the cave, from karst regions to the northeast of the cave, and the similar karst regions west of Wilson Creek. Large areas of water loss and potential water loss, both upstream and downstream of U. S. Highway 60, would be inundated by water in the proposed lake. The loss of water into these sink areas and similar cavernous structures nearer the dam location would have an effect on the hydrologic conditions downstream.

South Creek

A possible dam site on South Creek, in the SW¼ Sec. 5, T. 28N., R. 22W., is above an area of significant known water loss. With a waterline elevation of 1200 feet, a lake of 150 acres would be created. The watershed of 6500 acres would give a watershed-to-lake ratio of 36:1. The South Creek dam would store an estimated maximum of 2500 acre feet of water as compared with approximately 4000 acre feet by the Wilson Creek dam. This is 60 percent as much storage for a lake that covers less than one-half the area.

The only known water loss area downstream of the proposed dam on South Creek is an area about 200 yards downstream of Highway FF.

It is estimated that this water loss zone takes about 2 cfs from the stream. The water loss here also reappears at Rader Spring.

Geophysical surveys conducted on the floodplain near the mouth of South Creek revealed the presence of anomalies similar to caves or cavities known elsewhere (Figure 18). This suggests that it may be economically unfeasible to seal off the water loss zone or to construct a channel change around it.

The Proposed Tertiary and Bypass Treatment Lagoon

Investigations of the proposed lagoon site near the sewage treatment plant during the fall of 1968 and winter of 1969, revealed the following information about the surface and subsurface geologic features. Dye tracing studies, geophysical surveys and backhoe exploration holes have assisted in this investigation (Figure 18).

Dye tracing revealed that Rader Spring is the major outlet for subsurface water from south of Springfield, water loss from South Creek, water loss from upper Wilson Creek and numerous cave systems to the north and west of Springfield. The work of Harvey and Skelton (4) has also shown that considerable water loss occurs at the sewage treatment plant where the plant effluent is discharged into Wilson Creek. Water loss is apparently into fractured Burlington-Keokuk Limestone along the south bank of Wilson Creek at this point. A large portion of the subsurface waters from these areas was thought to travel beneath the sewage treatment plant and the proposed lagoon on the Wilson Creek floodplain. Geophysical studies confirmed the idea that numerous small caves, joints and solution enlarged bedding planes exist under the floodplain area. This is in contrast to the original ideas that one or two major caves with large passageways transmitted the subsurface water.

Because of this lithologic change so close to the surface of the proposed lagoon site, a series of test pits were dug to determine the quality and quantity of material at the site. A line of test pits starting near the creek and running north just on the west side of the sinkhole revealed 2 1/2 to 3 feet of brown silty clay material overlying several feet of coarse chert gravels intermixed with clay on the floodplain. Approximately 3 feet of silty material overlies gravel on the first terrace to the north. The bedrock on the sloping hill to the north of the floodplain has approximately 2 feet of material overlying several feet of gravel before bedrock is encountered.

A series of test pits dug approximately 300 to 400 feet west indicate a deeper deposit of alluvial silty clay material. Three test pits on the western side of the area revealed approximately 5 feet of good clay material with about 1 1/2 feet of cherty clay gravels overlying the Burlington bedrock.

Water loss at the sewage treatment plant was probably caused by construction of the outfall pipe which discharges effluent into Wilson Creek at right angles, with no stilling basin to reduce the energy of the effluent being discharged. Force of the effluent discharging into the narrow Wilson Creek channel has caused erosion of alluvial materials from the bedrock surface, thus exposing permeable Burlington-

Keokuk Limestone and providing entry for the sewage effluent into the groundwater conduits passing beneath the sewage treatment plant. Provision for discharging the effluent parallel to the flow of Wilson Creek should be made. This reduction of erosive capacity of the effluent would greatly reduce the possibility of eroding Wilson Creek to bedrock and causing further water loss into underground drainageways. The dilution of the plant effluent with resurging groundwater will enhance the quality of the water.

From the backhoe test pit study recommendations were made. Since they were of considerable detail, it was decided to list them in this appendix rather than in the main report.

Where the depth of water is to be in excess of normal depths in a lagoon, two to three feet of well compacted clay material should be placed as a pad on the lagoon bottom instead of one foot as previously recommended. Ten to fifteen foot depths of water over gravels or bedrock joints could cause blowouts and excessive water loss to the subsurface.

The northeastern portion of the proposed lagoon should be constructed so that it does not block the flow of water from Tube Cave. During periods of heavy rainfall, reversal of direction of flow has been noted. If the lagoon embankment is butted against the existing filter bed embankment without provisions for drainage from Tube Cave, erosion, flooding or collapse of the lagoon dike could result from ponding of water. If a flow augmentation dam is constructed on Wilson Creek above the sewage treatment plant, Tube Cave may well have a permanent reverse flow.

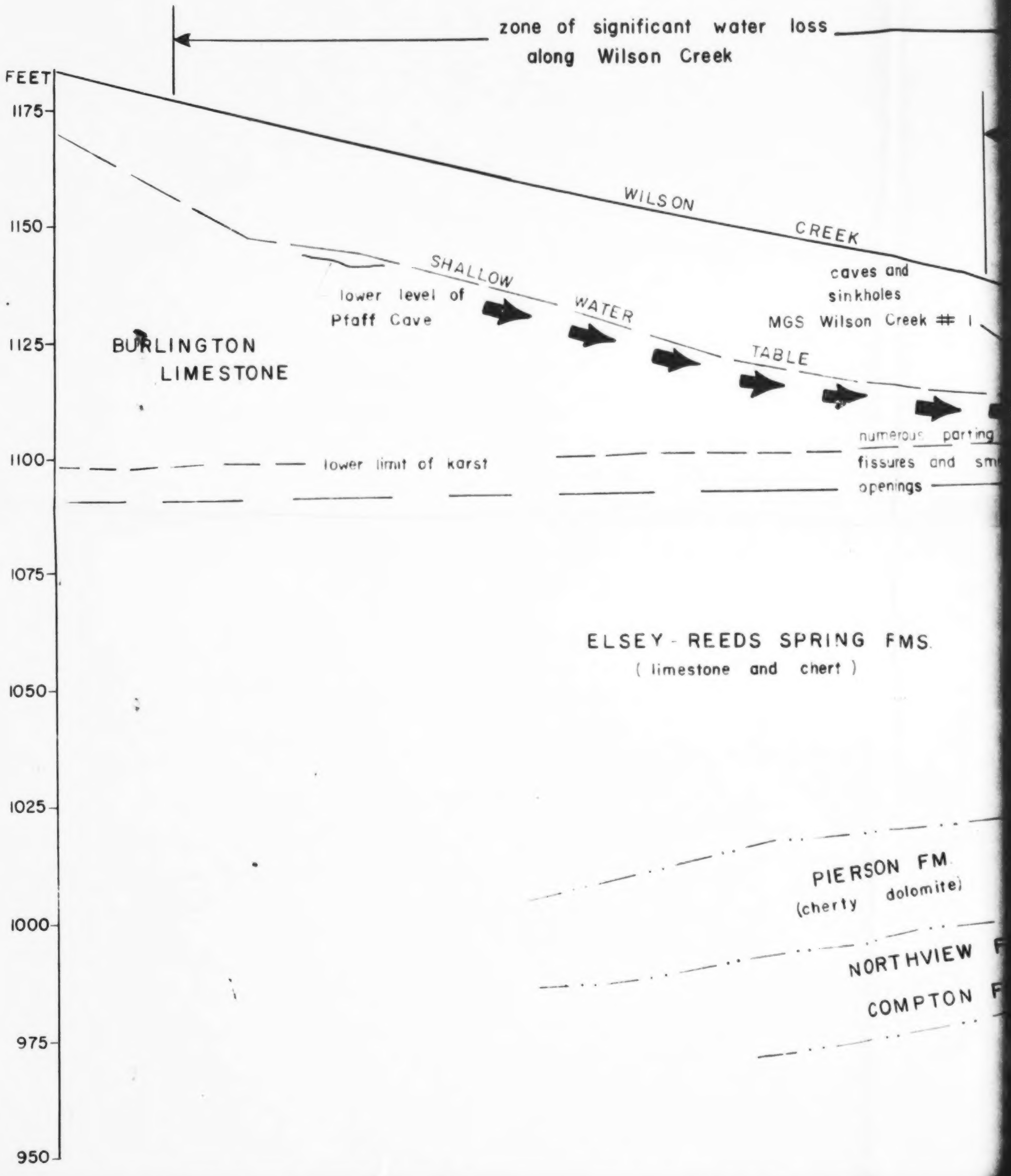
It will be necessary to determine the width of channel necessary between the lagoon dike and the east valley wall of Wilson Creek to allow sufficient capacity of flood conditions. Riprap may be necessary to prevent erosion of the dike during periods of high water.

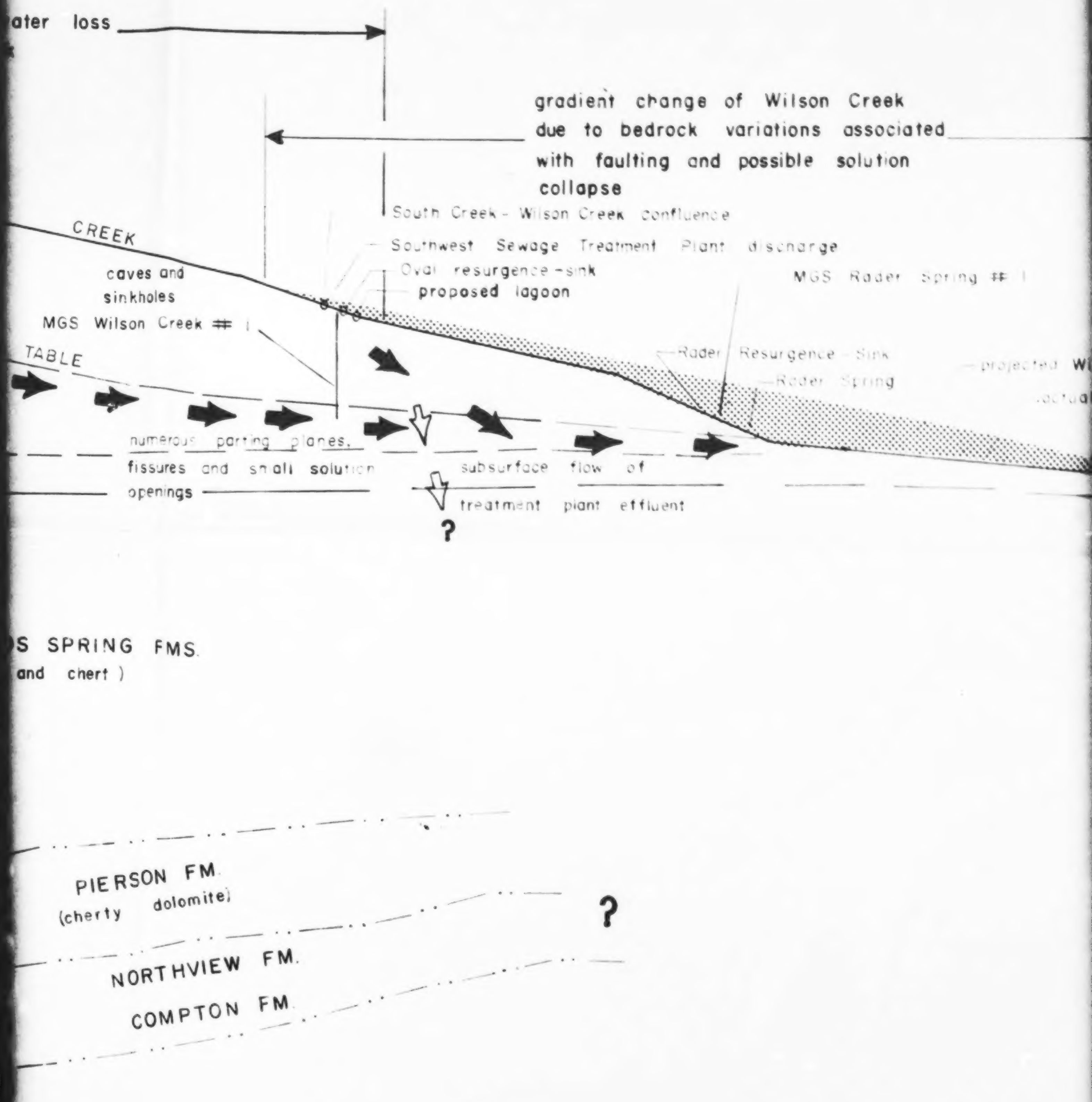
Widening of the stream channel of Wilson Creek will intercept a small resurgent sink called Lagoon Sink, on the right bank at station 11+00, 150 feet left (approximately). This small sinkhole could intercept large amounts of the streamflow from Wilson Creek and the discharge from the proposed lagoon. It is recommended that this sinkhole be investigated by excavating the debris from the orifice. Examination after excavation may determine if it is feasible to plug the surface waters from going to the subsurface. This sinkhole or its subsurface channel may extend into the lagoon area for some distance.

The gravels encountered in bedrock on the eastern side of the lagoon area and on the northern slope above the lagoon area could be used on the outside of the dike in the areas of the widened stream channel and the diversion ditch for the sinkhole and the cave. When compacted, this material should provide adequate protection against erosion during high water in the streams.

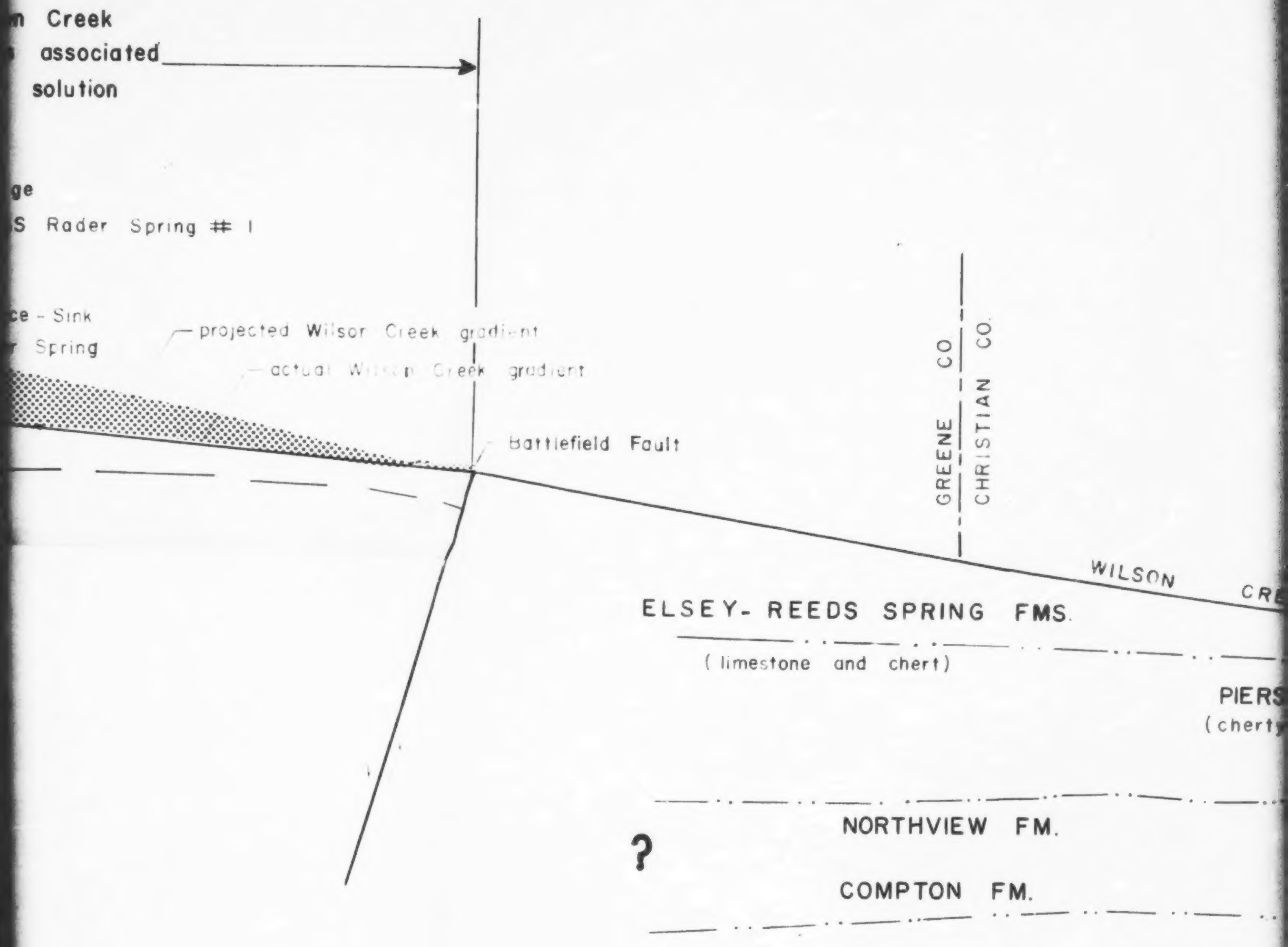
Applications of bentonite or other sealant material would be helpful, but is not deemed necessary in the padded area of the lagoon bottom.

The silty clay material obtained from widening of the present channel could be used as borrow material in the padded area of the lagoon bottom, and in the center portion of the east and south dike. The outside of the dike could be built with the heavy chert gravels and compacted. The gravels are located on the east side of the lagoon and on the lower slopes of the pasture.


zone of significant water loss
along Wilson Creek
FEET
1175
1150
1125
1100
1075
1050
1025
1000
975
950
WILSON CREEK
SHALLOW WATER TABLE
lower level of
Pfaff Cave
caves and
sinkholes
MGS Wilson Creek # 1
BURLINGTON
LIMESTONE
numerous parting
fissures and sm
openings
lower limit of karst
ELSEY - REEDS SPRING FMS.
(limestone and chert)
PIERSON FM.
(cherty dolomite)
NORTHVIEW F
COMPTON F


ater loss
gradient change of Wilson Creek due to bedrock variations associated with faulting and possible solution collapse
South Creek - Wilson Creek confluence
Southwest Sewage Treatment Plant discharge
Oval resurgence - sink
proposed lagoon
MGS Rader Spring # 1
CREEK
caves and sinkholes
MGS Wilson Creek # 1
TABLE
Rader Resurgence - Sink
Rader Spring
projected Wi
actual
numerous parting planes, fissures and small solution openings
subsurface flow of treatment plant effluent
?
OS SPRING FMS.
and chert)
PIERSON FM.
(cherty dolomite)
?
NORTHVIEW FM.
COMPTON FM.

B GEOLOGIC CROSS SECTIO


m Creek
associated
solution
ge
S Rader Spring # 1
ce - Sink
r Spring
projected Wilson Creek gradient
actual Wilson Creek gradient
Battlefield Fault
GREENE CO.
CHRISTIAN CO.
WILSON
CRE
ELSEY- REEDS SPRING FMS.
(limestone and chert)
PIERS
(cherty
?
NORTHVIEW FM.
COMPTON FM.

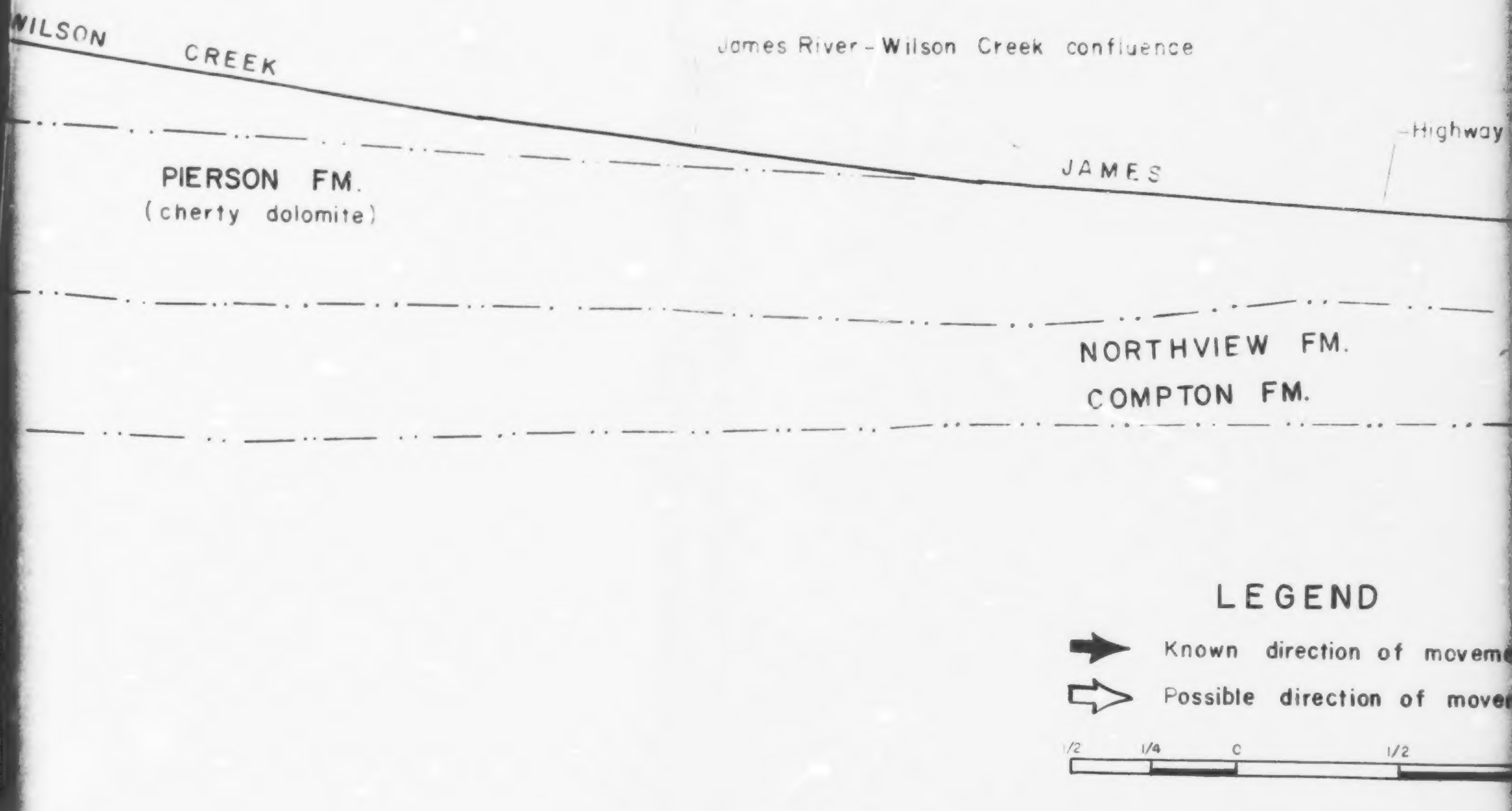
SS SECTION ALONG WILSON CREEK PROFILE

Showing Relationship of Geologic Structure, Wat

Creek, Surface Water Loss and R

C

FIGURE 17

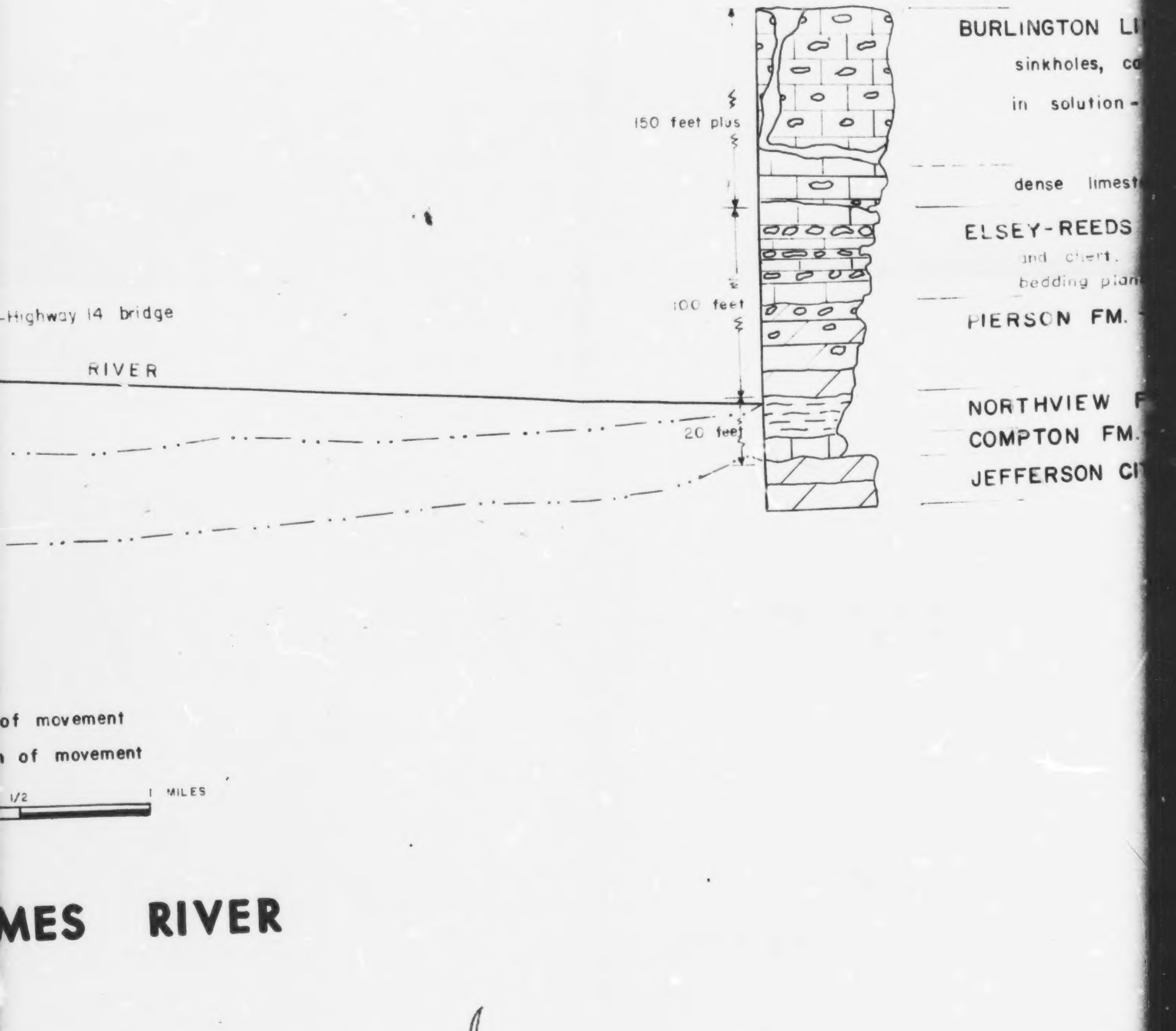

WILSON CREEK
James River - Wilson Creek confluence
Highway
JAMES
PIERSON FM.
(cherty dolomite)
NORTHVIEW FM.
COMPTON FM.
LEGEND
Known direction of moveme
Possible direction of move
1/2
1/4
0
1/2

ROFILE FROM PFAFF CAVE TO JAMES

ure, Water Table, Gradient of Wilson

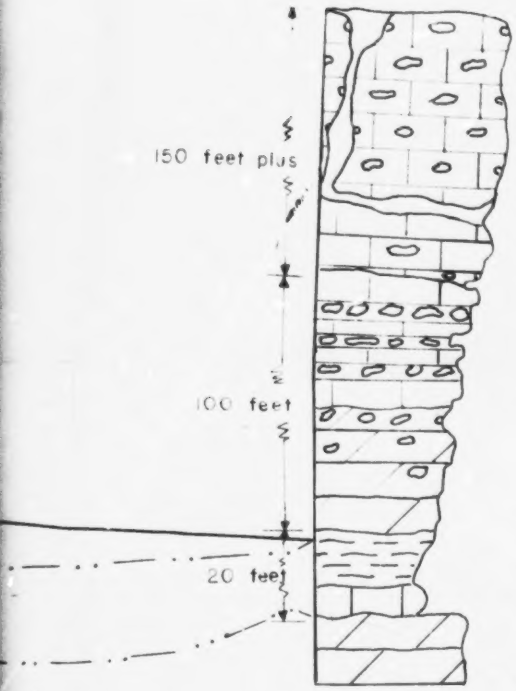
s and Resurgences

17


BURLINGTON LI
sinkholes, co
in solution-
dense limest
ELSEY-REEDS
and chert.
bedding plan
PIERSON FM.
NORTHVIEW F
COMPTON FM.
JEFFERSON CI
150 feet plus
100 feet
20 feet
-Highway 14 bridge
RIVER
of movement
n of movement
1/2
1 MILES

MES RIVER

MISSOURI GEOLOG



BURLINGTON LIMESTONE - massive, cherty with sinkholes, caves and fissures, water bearing in solution - enlarged openings.

dense limestone, some chert

ELSEY-REEDS SPRING FMS. - interbedded limestone and chert. Water bearing along fissures, bedding planes and small solution channels.

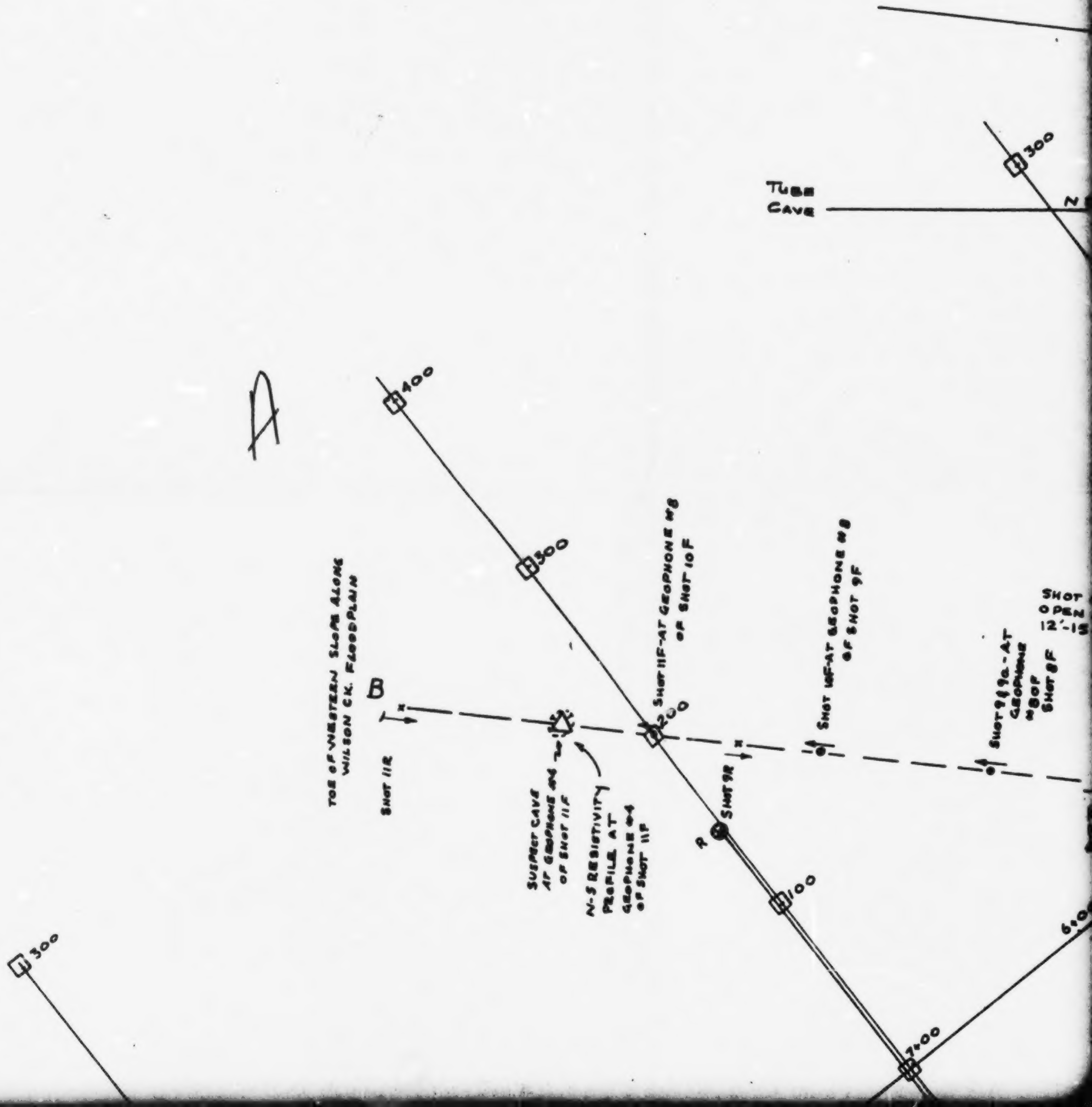
PIERSON FM. - dolomite, cherty near upper part

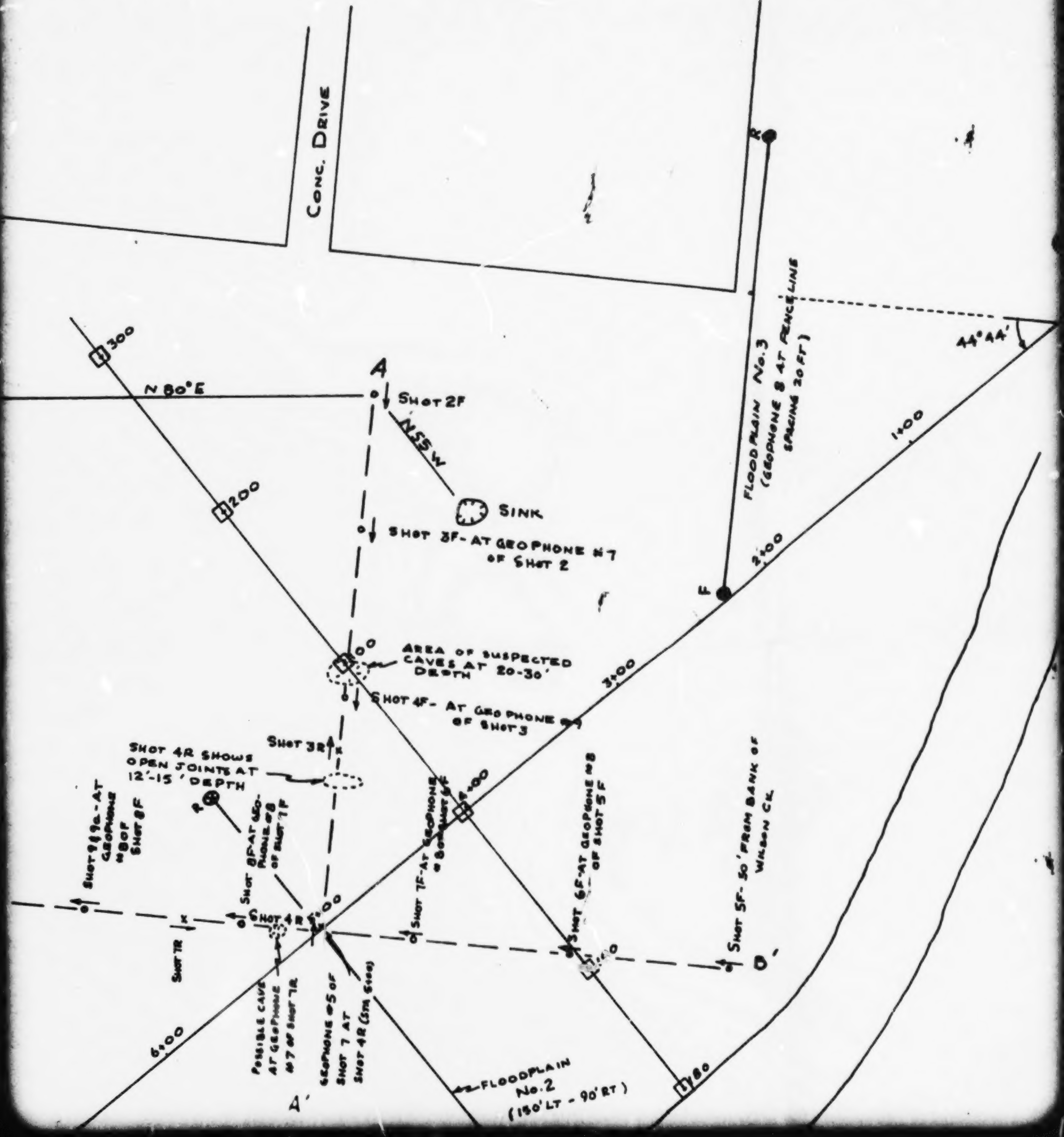
NORTHVIEW FM. - shale

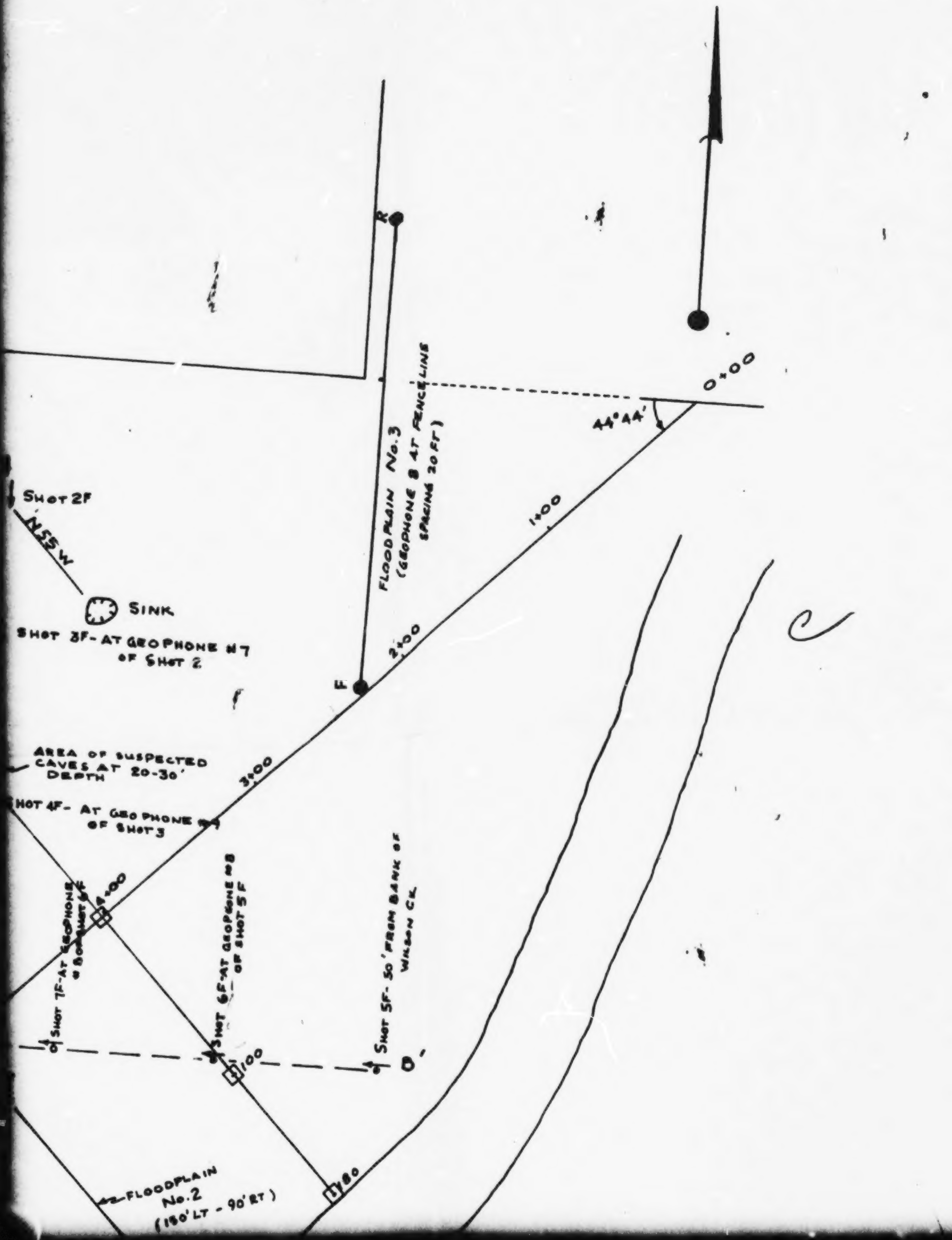
COMPTON FM. - limestone

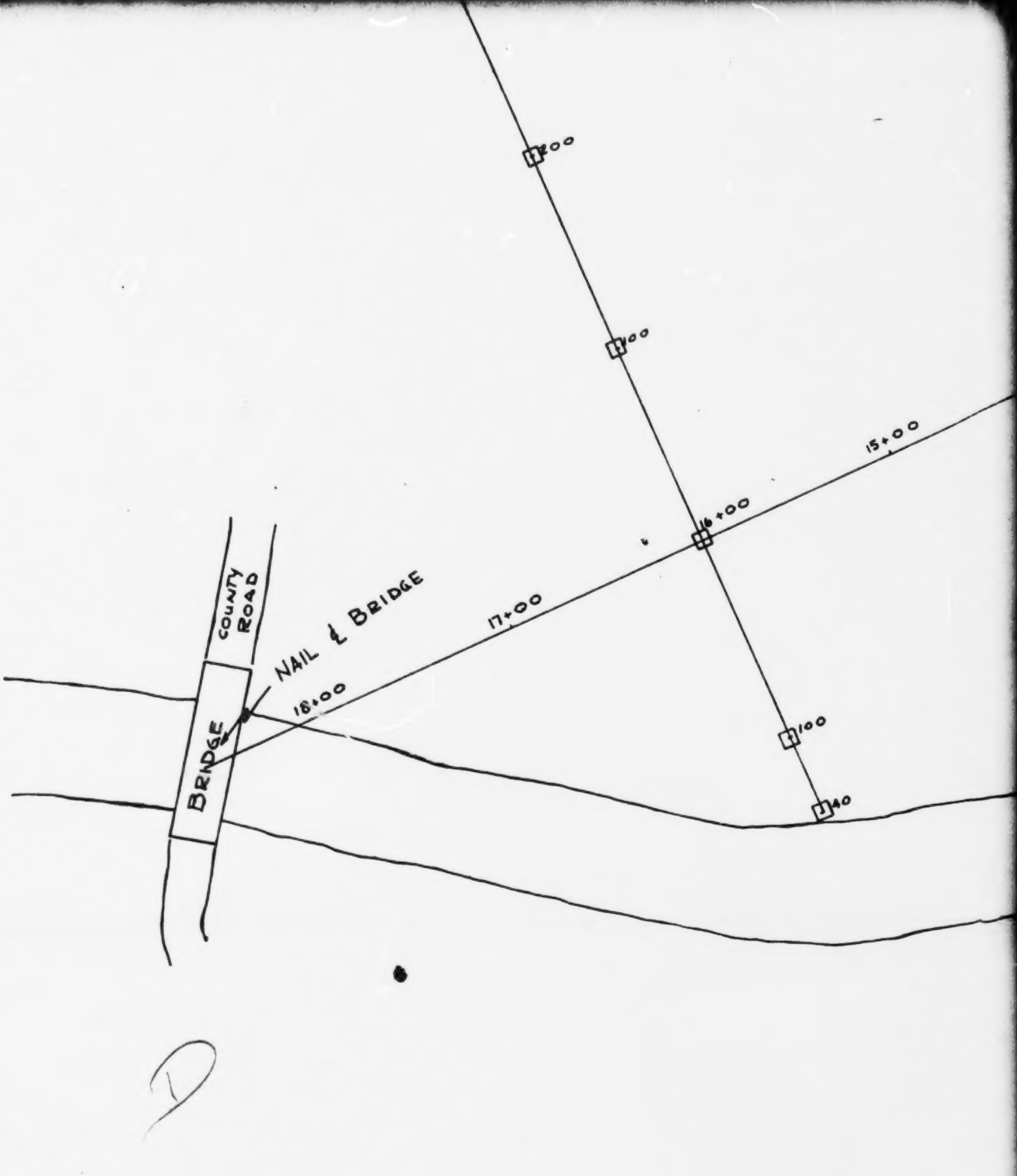
JEFFERSON CITY DOLOMITE - COTTER DOLOMITE

MISSOURI GEOLOGICAL SURVEY & WATER RESOURCES
MARCH 1969

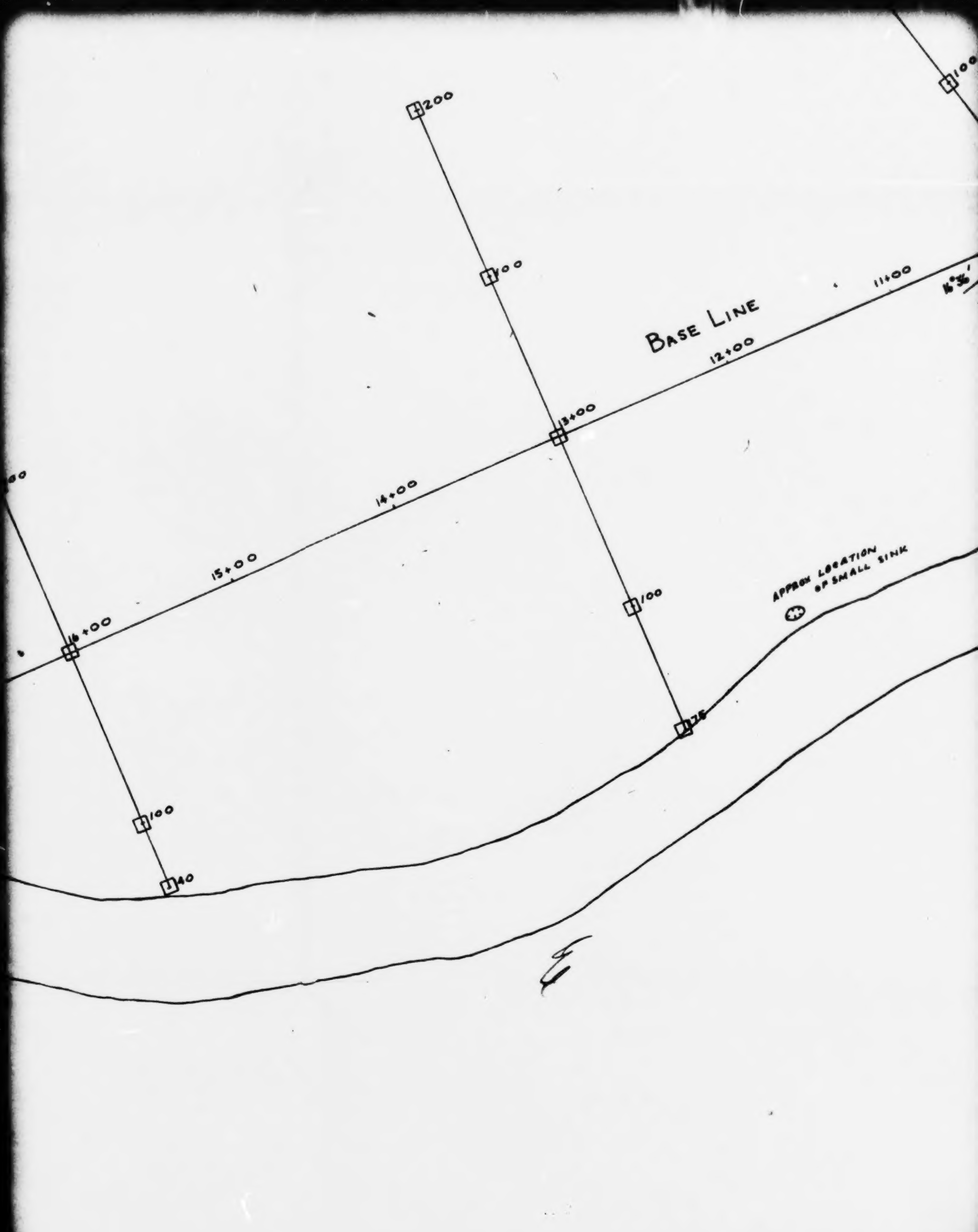

A
B
300
TUBE CAVE
N
400
300
200
100
300
7+00
6+0
R
TOE OF WESTERN SLOPE ALONG WILSON CK. FLOODPLAIN
SHOT 11R
SUSPECT CAVE AT GEOPHONE #4 OF SHOT 11F
N-S RESISTIVITY PROFILE AT GEOPHONE #4 OF SHOT 11F
SHOT 11F-AT GEOPHONE #8 OF SHOT 10F
SHOT 9R
SHOT 10F-AT GEOPHONE #8 OF SHOT 9F
SHOT 9 & 9a-AT GEOPHONE #8 OF SHOT 8F
SHOT
OPEN
12'-15

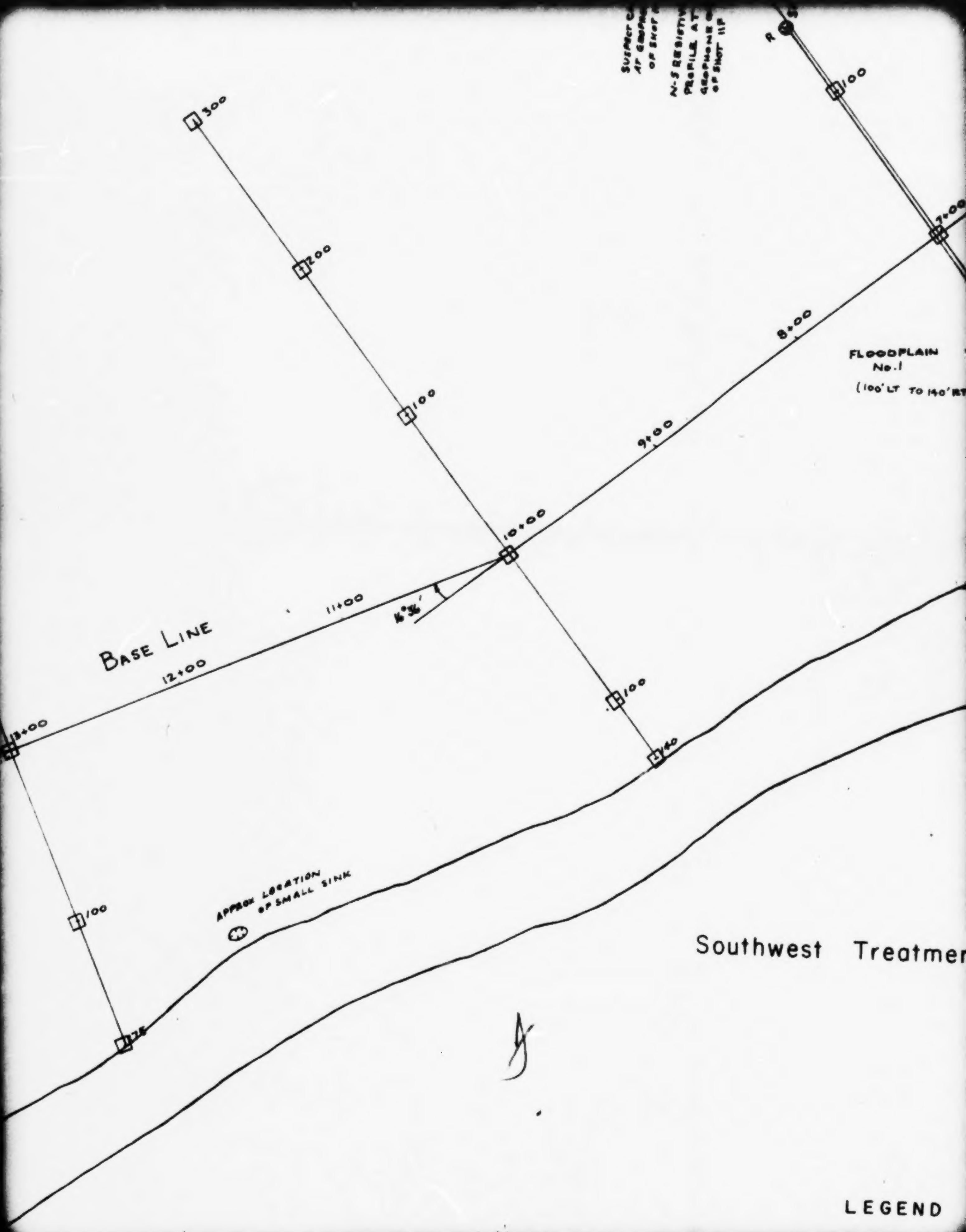

CONC. DRIVE
R
F
FLOODPLAIN No. 3
(GEOPHONE 8 AT FENCE LINE
SPACING 20 FT)
44°44'
1+00
2+00
3+00
4+00
5+00
6+00
300
200
0°
A
A'
B'
N 80° E
SHOT 2F
N55W
SINK
SHOT 3F- AT GEOPHONE #7
OF SHOT 2
AREA OF SUSPECTED
CAVES AT 20-30'
DEPTH
SHOT 4F- AT GEOPHONE
OF SHOT 3
SHOT 3R
SHOT 4R SHOWS
OPEN JOINTS AT
12'-15' DEPTH
R
SHOT 9 & 9a - AT
GEOPHONE
#8 OF
SHOT 8F
SHOT 8F AT GEO-
PHONE #8
OF SHOT 7F
SHOT 4R
SHOT 7R
POSSIBLE CAVE
AT GEOPHONE
#7 OF SHOT 7R
GEOPHONE #5 OF
SHOT 7 AT
SHOT 4R (STA 5+00)
SHOT 7F-AT GEOPHONE
#8 OF SHOT 6F
SHOT 6F-AT GEOPHONE #8
OF SHOT 5F
SHOT 5F- 50' FROM BANK OF
WILSON CK.
FLOODPLAIN
No. 2
(150' LT - 90' RT)
1+80

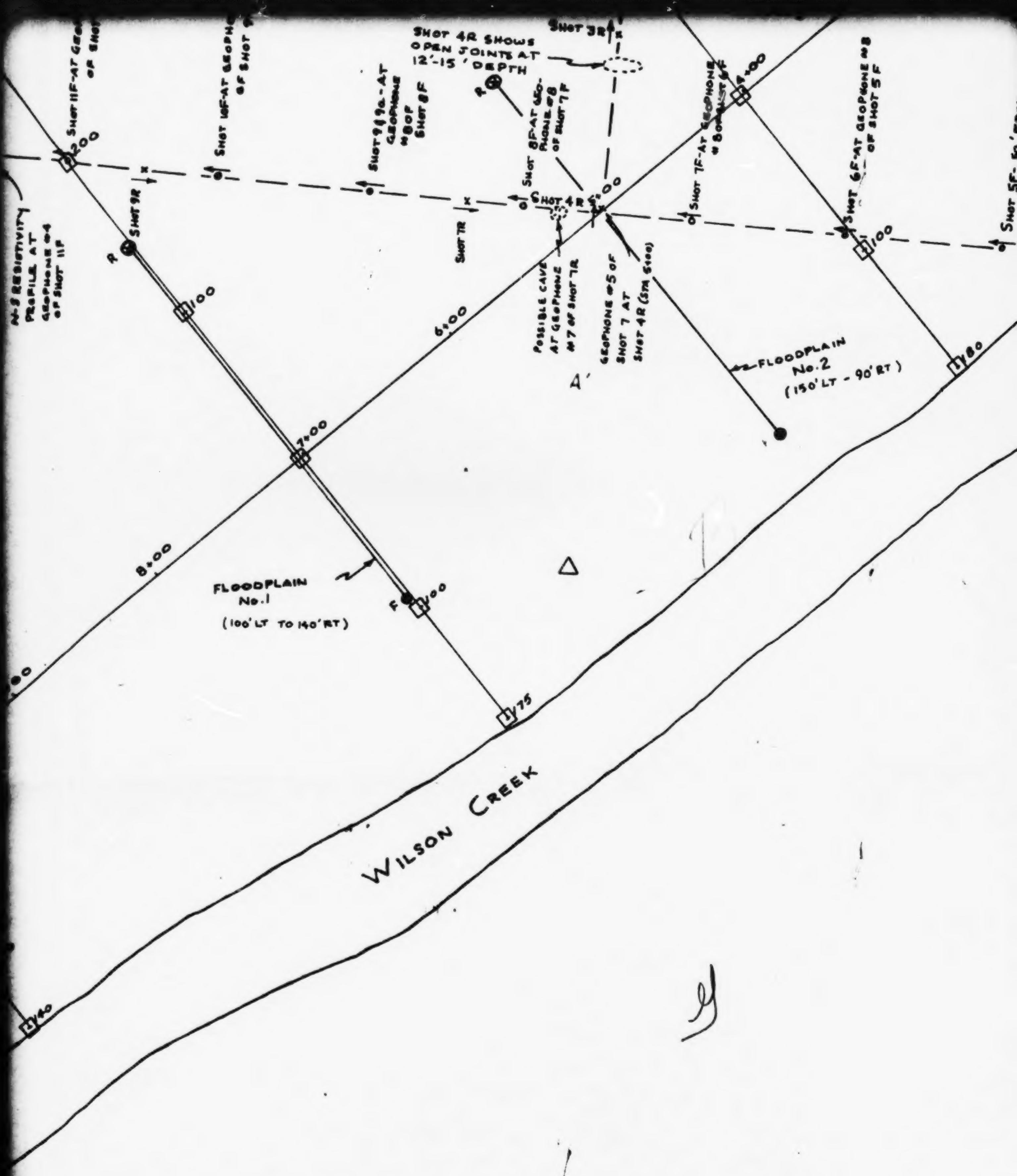
R
0+00
44°44'
1+00
2+00
3+00
4+00
F
FLOODPLAIN No. 3 (GEOPHONE 8 AT FENCE LINE SPACING 20 FT)
SHOT 2F
N55W
SINK
SHOT 3F- AT GEOPHONE #7 OF SHOT 2
AREA OF SUSPECTED CAVES AT 20-30' DEPTH
HOT 4F- AT GEOPHONE #4 OF SHOT 3
SHOT 7F-AT GEOPHONE #8 OF SHOT 6F
SHOT 6F-AT GEOPHONE #8 OF SHOT 5F
SHOT 5F- 50' FROM BANK OF WILSON CK
0
100
0'
180
FLOODPLAIN No. 2 (150' LT - 90' RT)
C


200
100
15+00
16+00
17+00
NAIL ℄ BRIDGE
COUNTY ROAD
18+00
BRIDGE
100
40

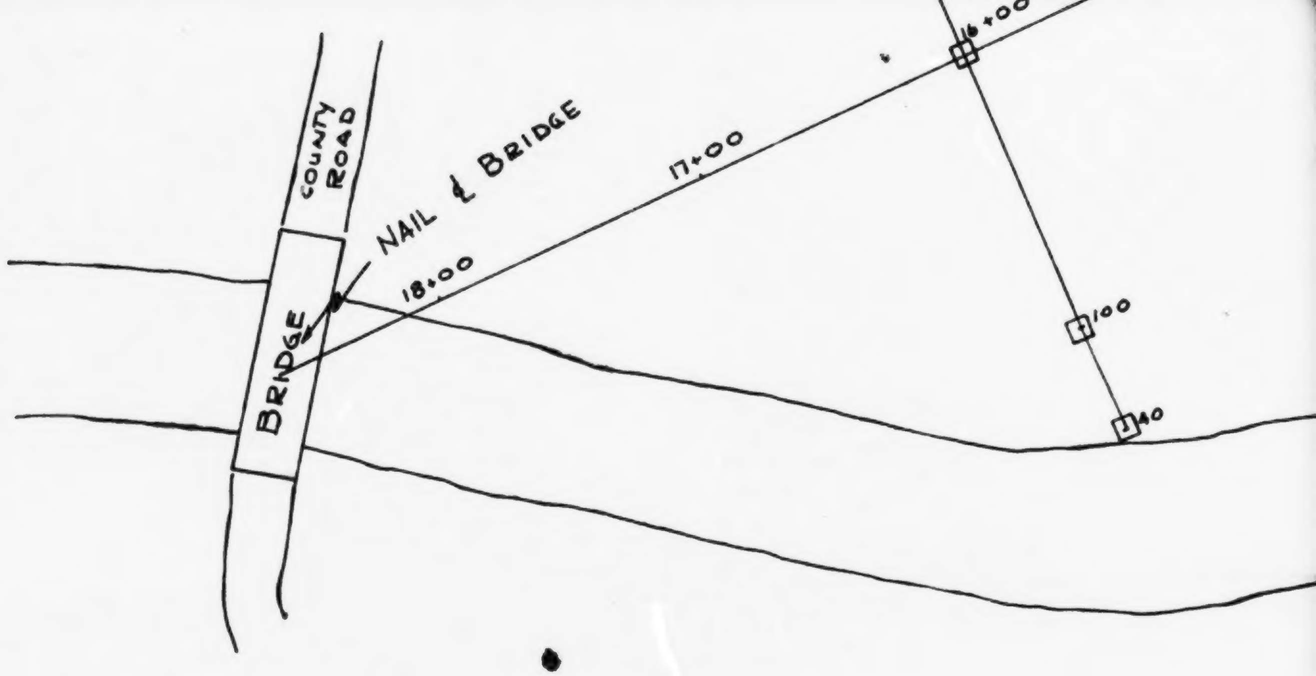
D


100
200
100
BASE LINE
11+00
16°30'
12+00
13+00
14+00
15+00
16+00
00
100
APPROX LOCATION OF SMALL SINK
75
100
40


SUSPECT C
AT GEOPH
OF SHOT
N-S RESISTIV
PROFILE AT
GEOPHONE
OF SHOT 11P
R
100
300
200
100
7+00
8+00
9+00
10+00
FLOODPLAIN
No. 1
(100' LT TO 140' RT
11+00
16°36'
BASE LINE
12+00
13+00
100
140
APPROX LOCATION
OF SMALL SINK
100
75
Southwest Treatmen
LEGEND


SHOT 4R SHOWS OPEN JOINTS AT 12'-15' DEPTH
SHOT 3R
SHOT 11F-AT GEO OF SHOT
SHOT 10F-AT GEOPHO OF SHOT
SHOT 9 & 9a-AT GEOPHONE #8 OF SHOT 8F
SHOT 8F-AT GEOPHONE #8 OF SHOT 7F
SHOT 7F-AT GEOPHONE #8 OF SHOT 6F
SHOT 6F-AT GEOPHONE #8 OF SHOT 5F
SHOT 5F-
SHOT 9R
SHOT 7R
SHOT 4R
R
R
F
200
100
100
100
6+00
7+00
8+00
5+00
4+00
75
80
40
N-S RESISTIVITY PROFILE AT GEOPHONE #4 OF SHOT 11F
POSSIBLE CAVE AT GEOPHONE #7 OF SHOT 7R
GEOPHONE #5 OF SHOT 7 AT SHOT 4R (STA 5+00)
FLOODPLAIN No.2 (150' LT - 90' RT)
FLOODPLAIN No.1 (100' LT TO 140' RT)
A'
WILSON CREEK

Southwest Treatment Lagoon Site


COUNTY ROAD
NAIL ℄ BRIDGE
16+00
17+00
18+00
BRIDGE
100
40

D

WILSON CREEK PROJECT
GREENE COUNTY, MO

MISSOURI GEOLOGICAL SURVEY AND WATER RESOURCES

Location of Test Pits, Resistivity and Seismic Profiles

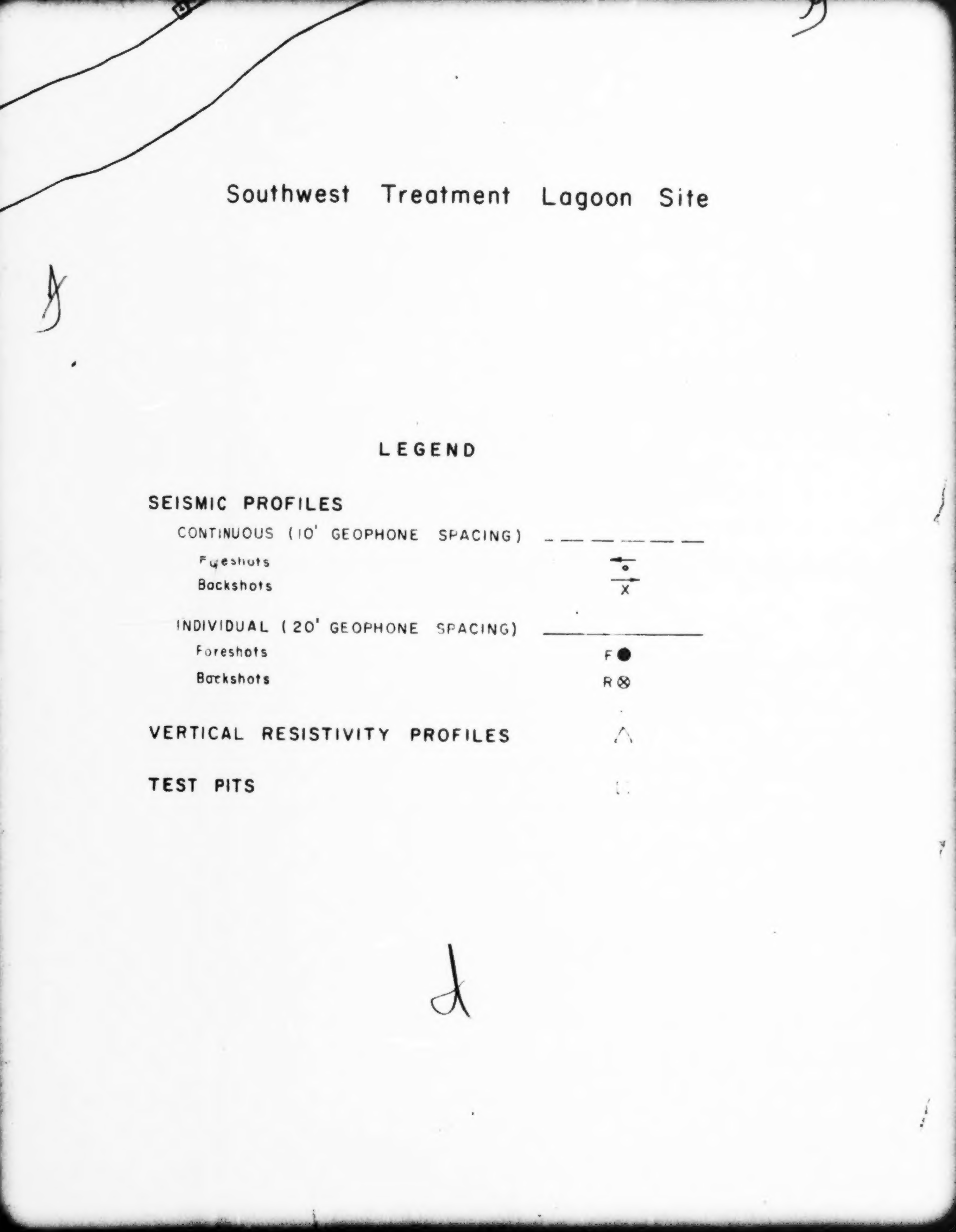
Southwest Treatment Lagoon Site

BASE MAP BY CITY OF SPRINGFIELD

FOR: FEDERAL WATER POLLUTION CONTROL AUTHORITY

SCALE: 1" = 60'

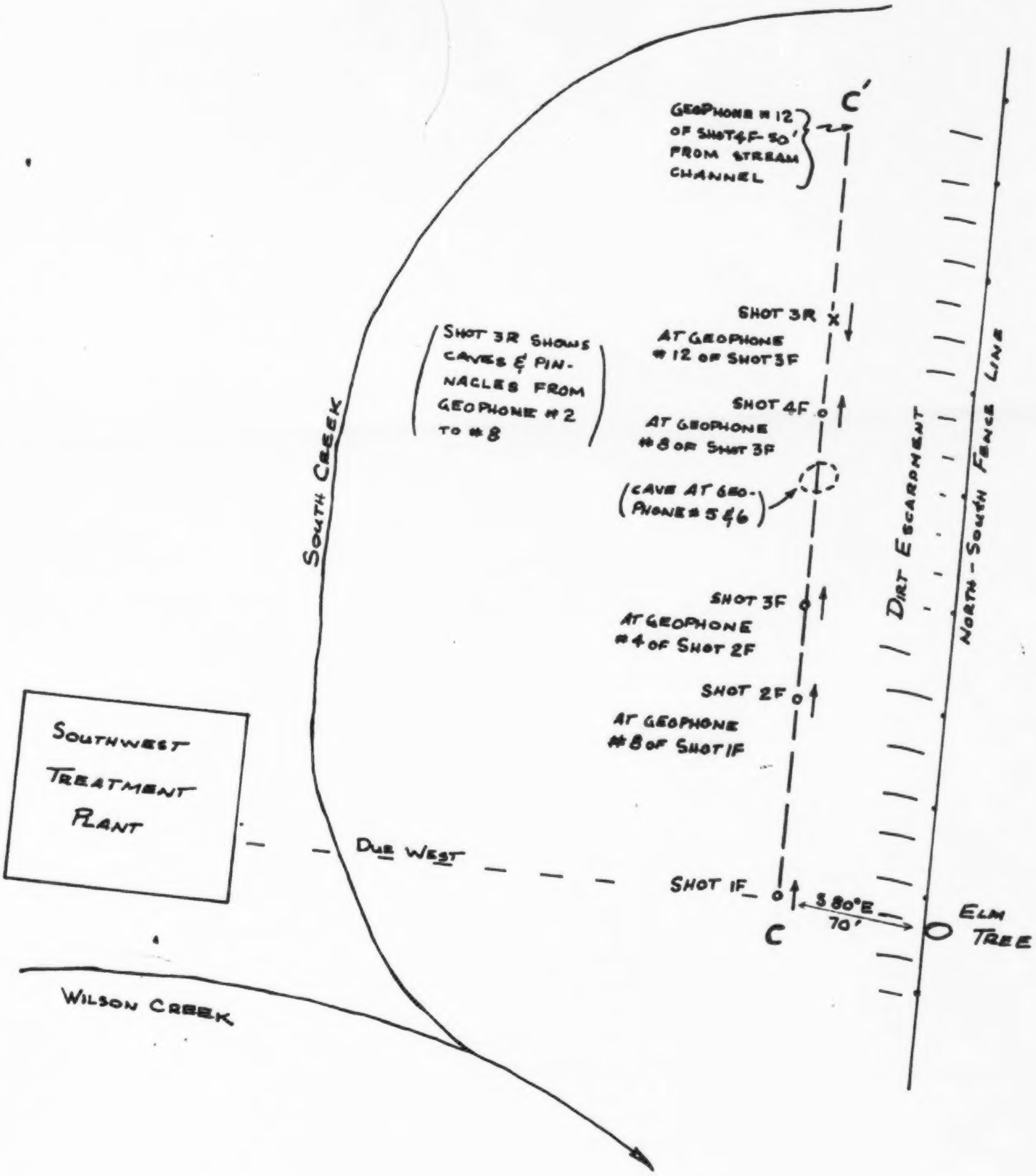
MARCH 1969



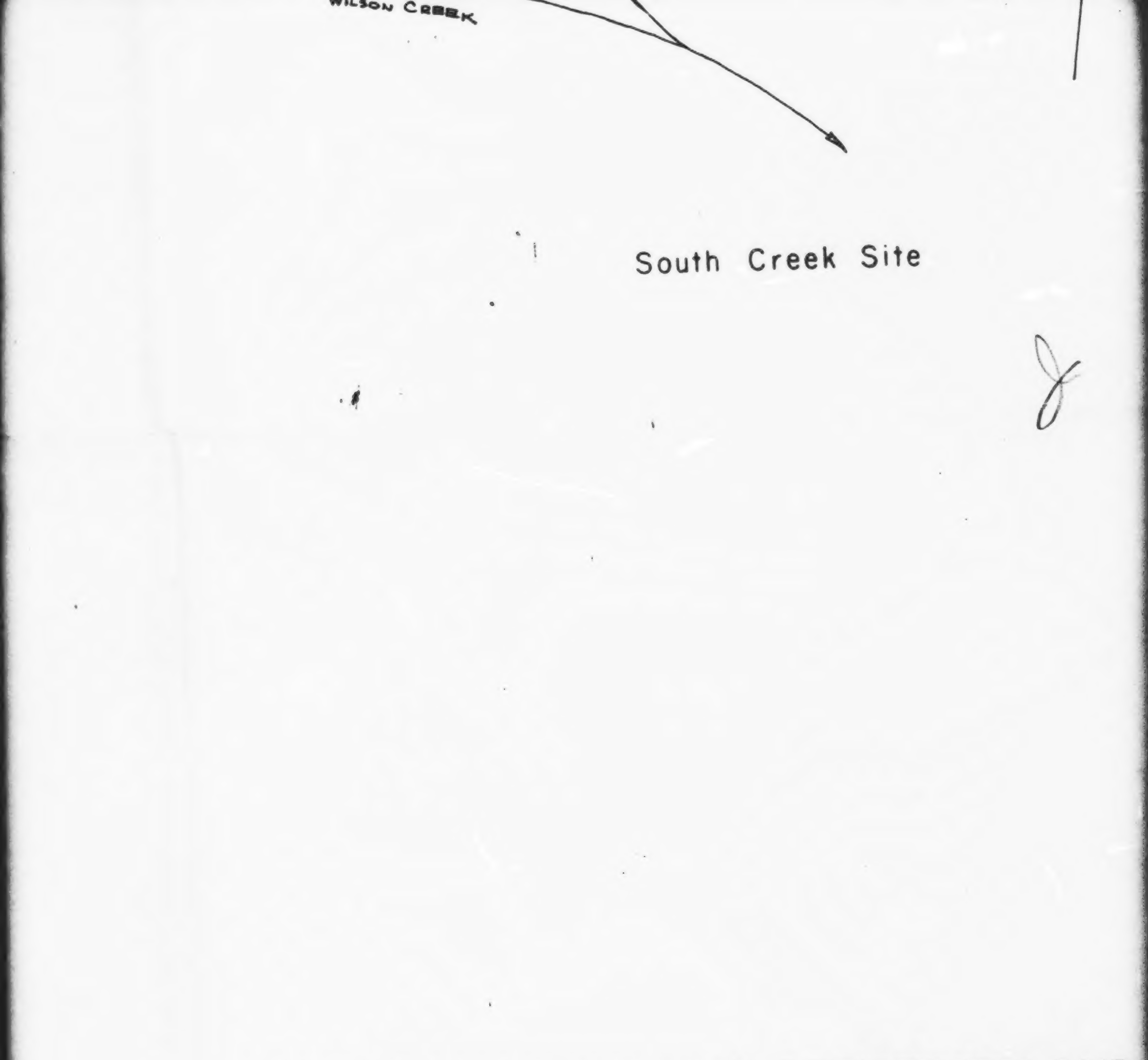
Southwest Treatment Lagoon Site

LEGEND

SEISMIC PROFILES	
CONTINUOUS (10' GEOPHONE SPACING)	— — — — — —
Foreshots	← o
Backshots	→ X
INDIVIDUAL (20' GEOPHONE SPACING)	————————
Foreshots	F ●
Backshots	R ⊗
VERTICAL RESISTIVITY PROFILES	∧
TEST PITS	□


GEOPHONE #12 OF SHOT 4F-50' FROM STREAM CHANNEL
C'
SHOT 3R
AT GEOPHONE #12 OF SHOT 3F
SHOT 3R SHOWS CAVES & PINNACLES FROM GEOPHONE #2 TO #8
SHOT 4F
AT GEOPHONE #8 OF SHOT 3F
CAVE AT GEOPHONE # 5 & 6
SHOT 3F
AT GEOPHONE #4 OF SHOT 2F
SHOT 2F
AT GEOPHONE #8 OF SHOT 1F
SHOT 1F
C
S 80°E
70'
ELM TREE
DIRT ESCARPMENT
NORTH-SOUTH FENCE LINE
SOUTH CREEK
SOUTHWEST TREATMENT PLANT
DUE WEST
WILSON CREEK

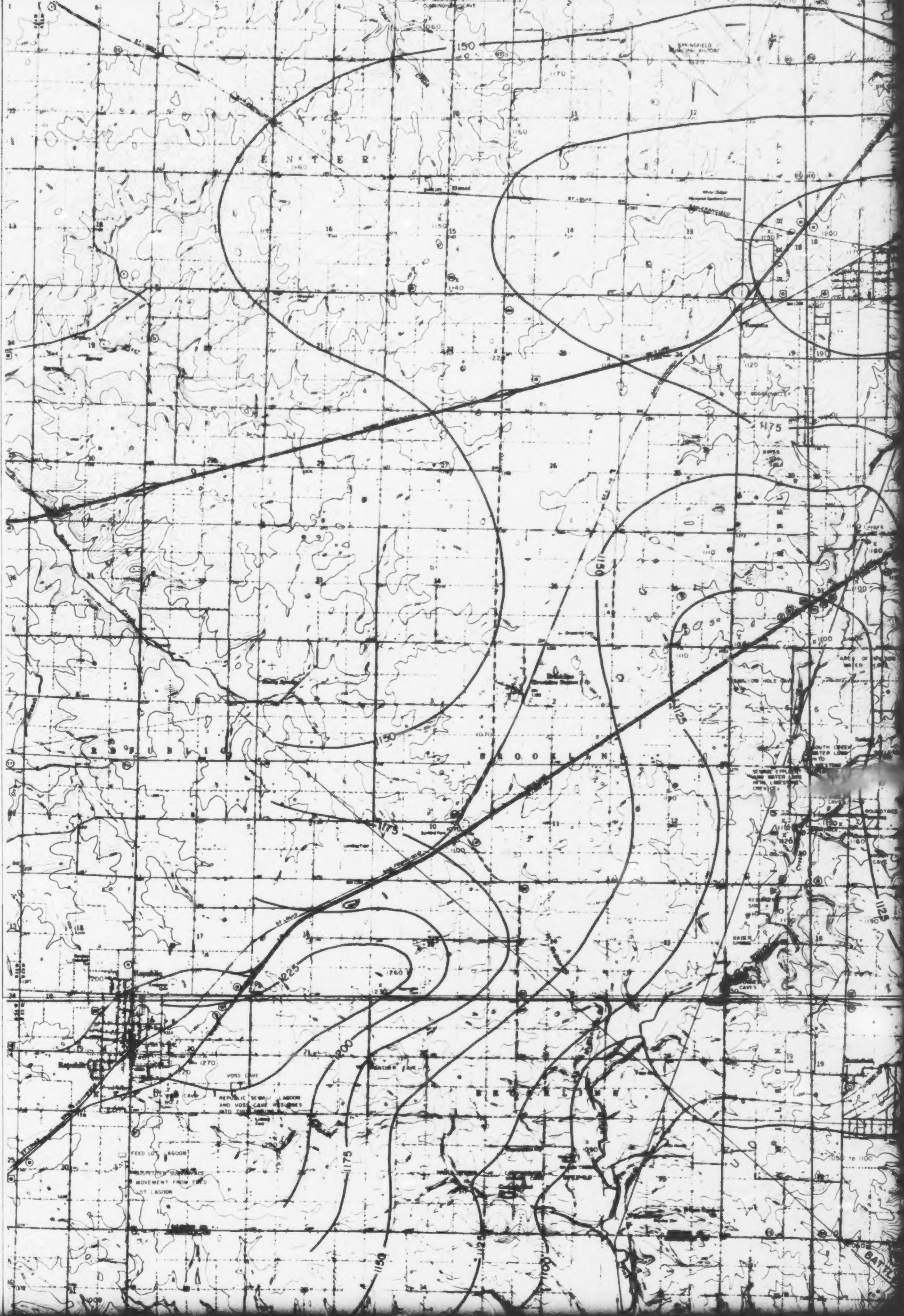
South Creek Site

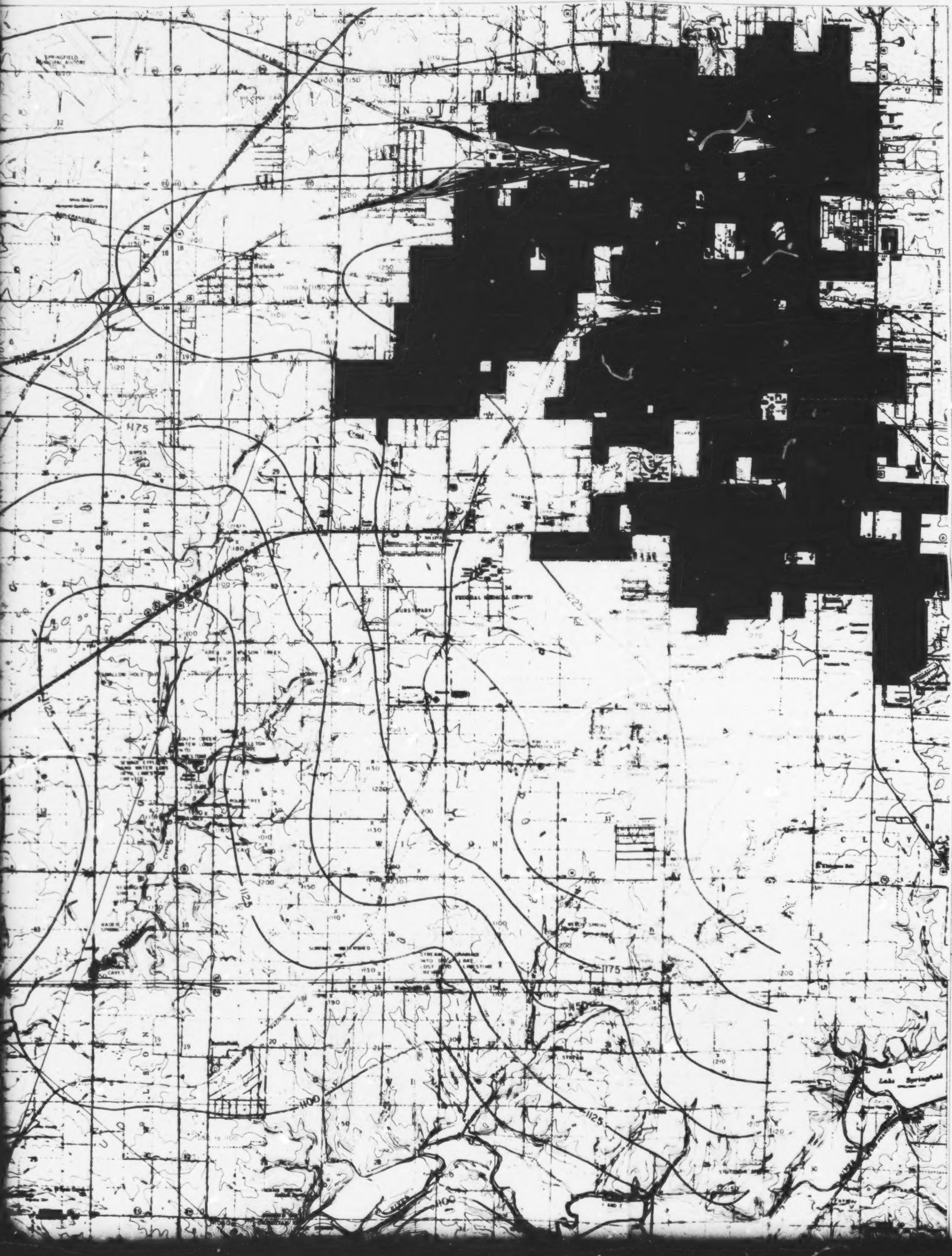

WILSON CREEK
South Creek Site
J

LOCATION OF TEST PITS, RESISTIVITY AND
SEISMIC PROFILES, SPRINGFIELD SOUTHWES
SEWAGE TREATMENT LAGOON SITES
FIGURE 18

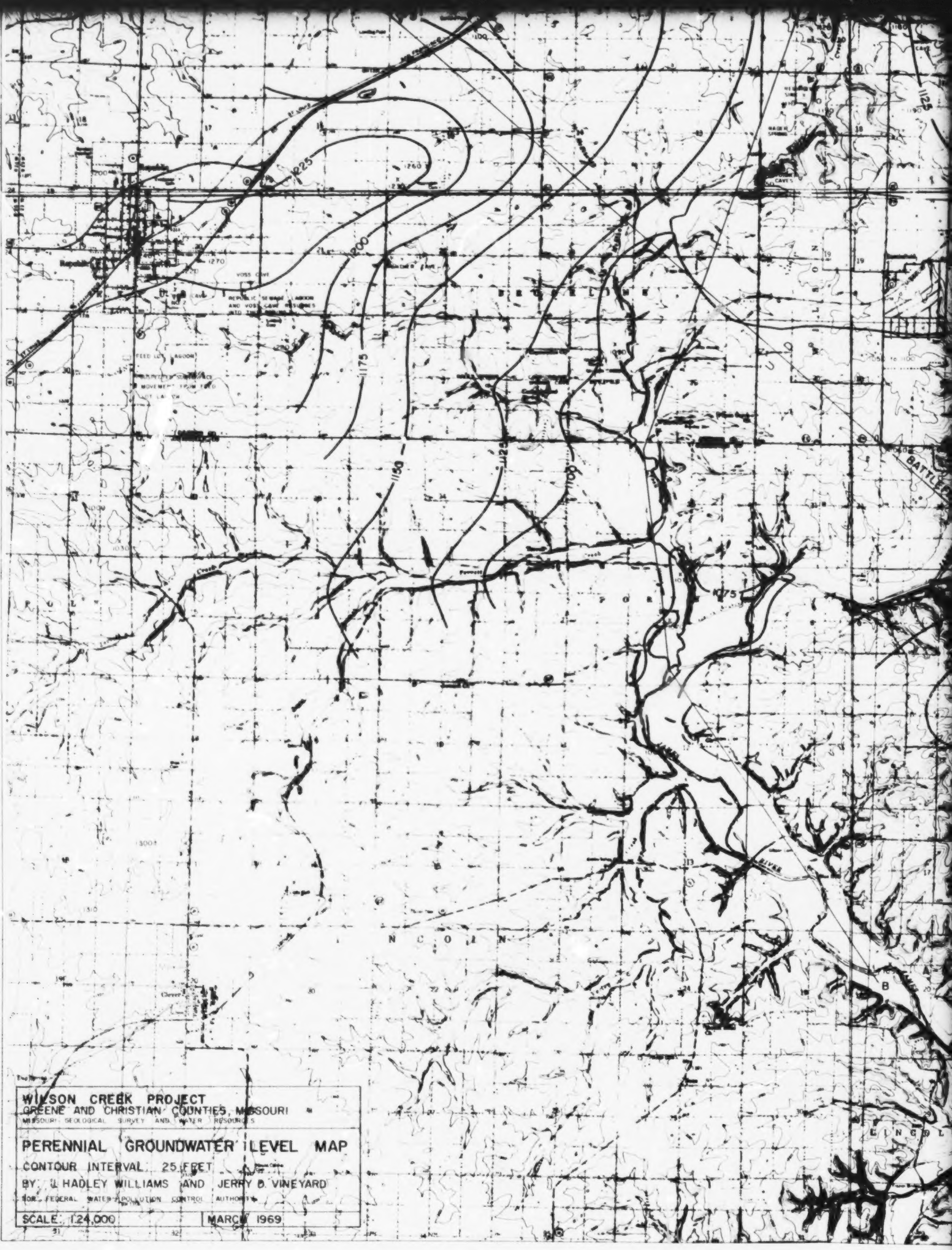
K

A


SPRINGFIELD MUNICIPAL AIRPORT
C E N T E R
1150
1175
1150
1125
1200
1225
1100
1270
1220
R E P U B L I C
B R O O K L I N E
Republic
VOSS CAVE
CAVE
NO 2
REPUBLIC SEWAGE LAGOON AND VOSS CAVE RESURGES INTO THE SPRING
FEED LOT LAGOON
SUSPECTED SUBSURFACE MOVEMENT FROM FEED LOT LAGOON
AREA OF WATER LOSS
SOUTH CREEK WATER LOSS
SEWAGE EFFLUENT WATER LOSS INTO LOSING CREVICES
BAKER SPRING
CAVES
1050 to 1100
BATTLE


SPRINGFIELD MUNICIPAL AIRPORT
1175
1125
1100
1175
1225
1200
W I L S O N
C L A Y
FEDERAL MEDICAL CENTER
Lake Springfield
1100
1125

B


1225
1200
1175
1150
1125
1100
1075
1260
1270
Republic
VOSS CAVE
REPUBLIC SEWAGE LAGOON AND VOSS CAVE
FEED LOT LAGOON
CAVES
Creek
RIVER
Clever
BATTLEF
N C O L N
L I N C O L

WILSON CREEK PROJECT
GREENE AND CHRISTIAN COUNTIES, MISSOURI
MISSOURI GEOLOGICAL SURVEY AND WATER RESOURCES

PERENNIAL GROUNDWATER LEVEL MAP

CONTOUR INTERVAL 25 FEET
BY J. HADLEY WILLIAMS AND JERRY D. VINEYARD
FOR FEDERAL WATER POLLUTION CONTROL AUTHORITY

SCALE: 1:24,000
MARCH 1969

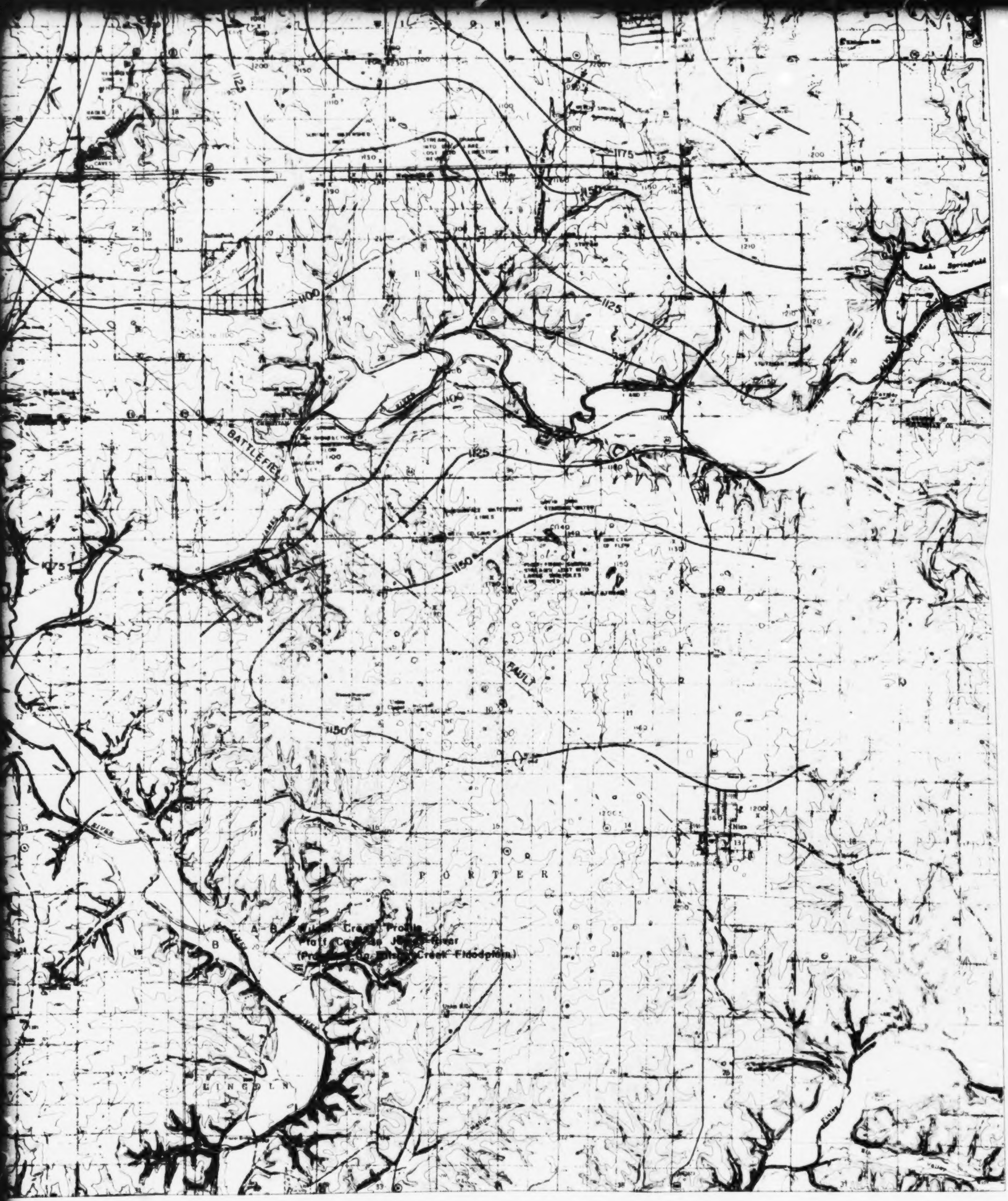
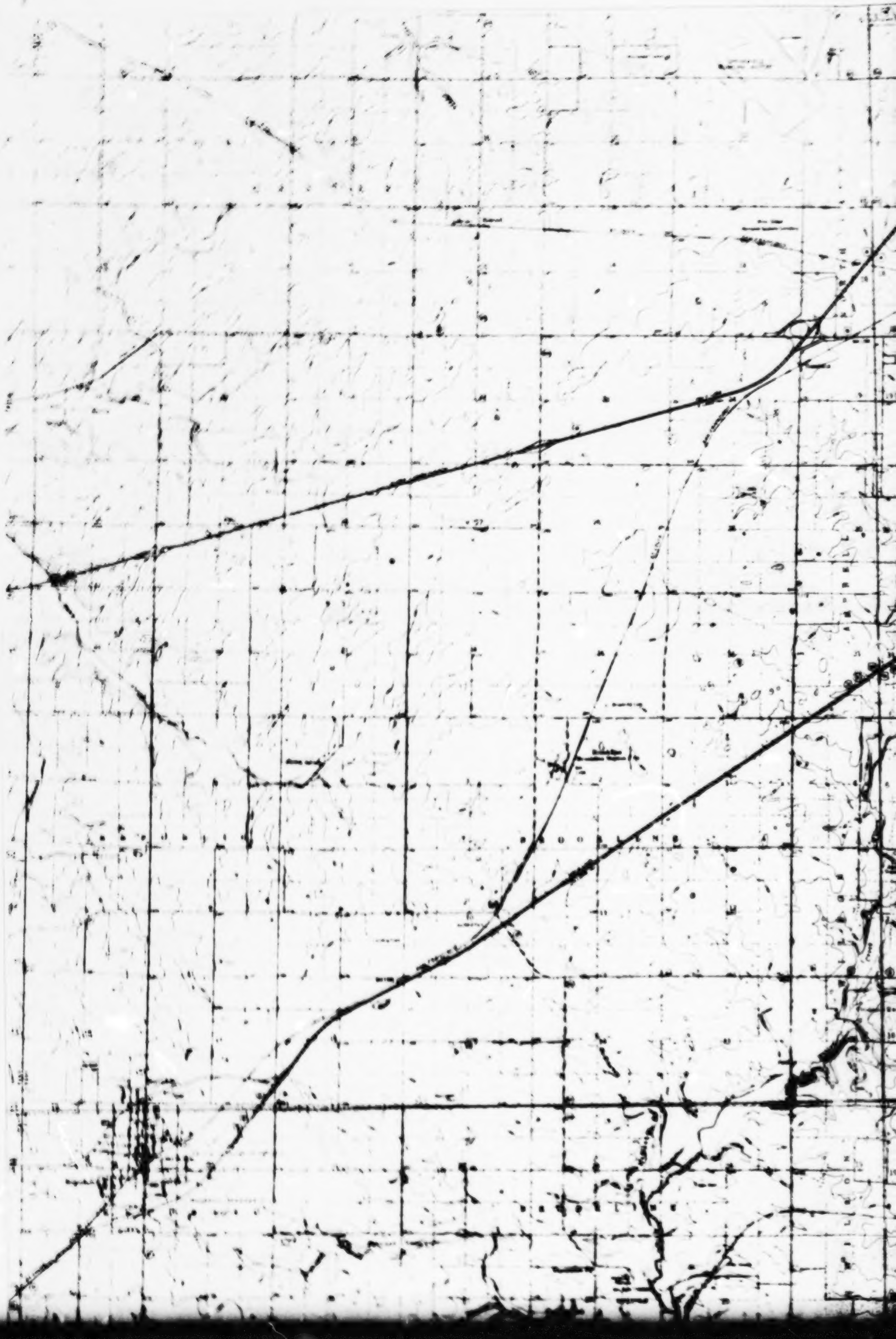
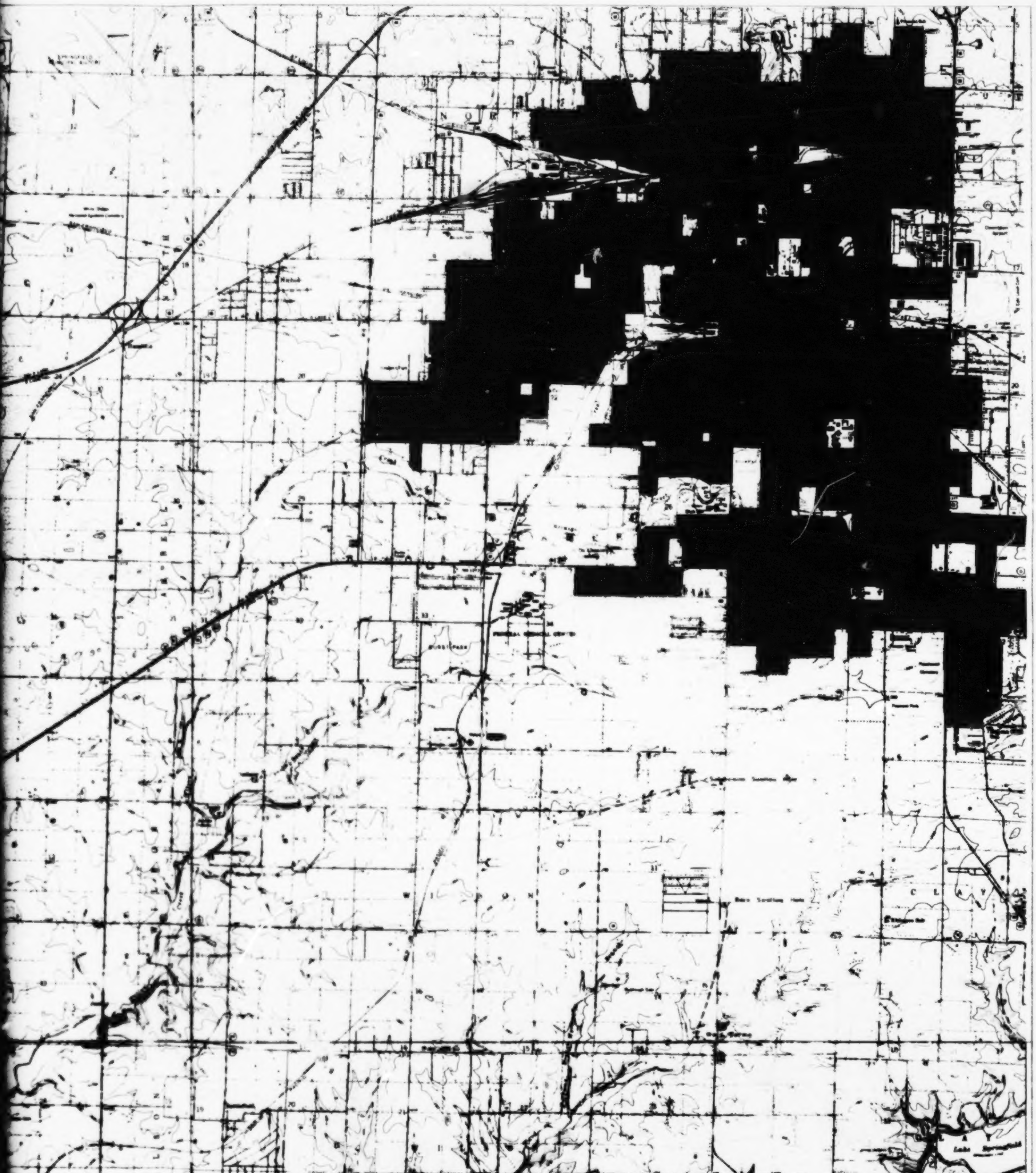

1125
1175
1150
1100
BATTLEFIELD
FAULT
PORTER
LINCOLN
Lake Springfield
Nixa
A - B Wilson Creek Profile
Profile Cont. on James River
(Profile along Wilson Creek Floodplain)
A
B
RIVER

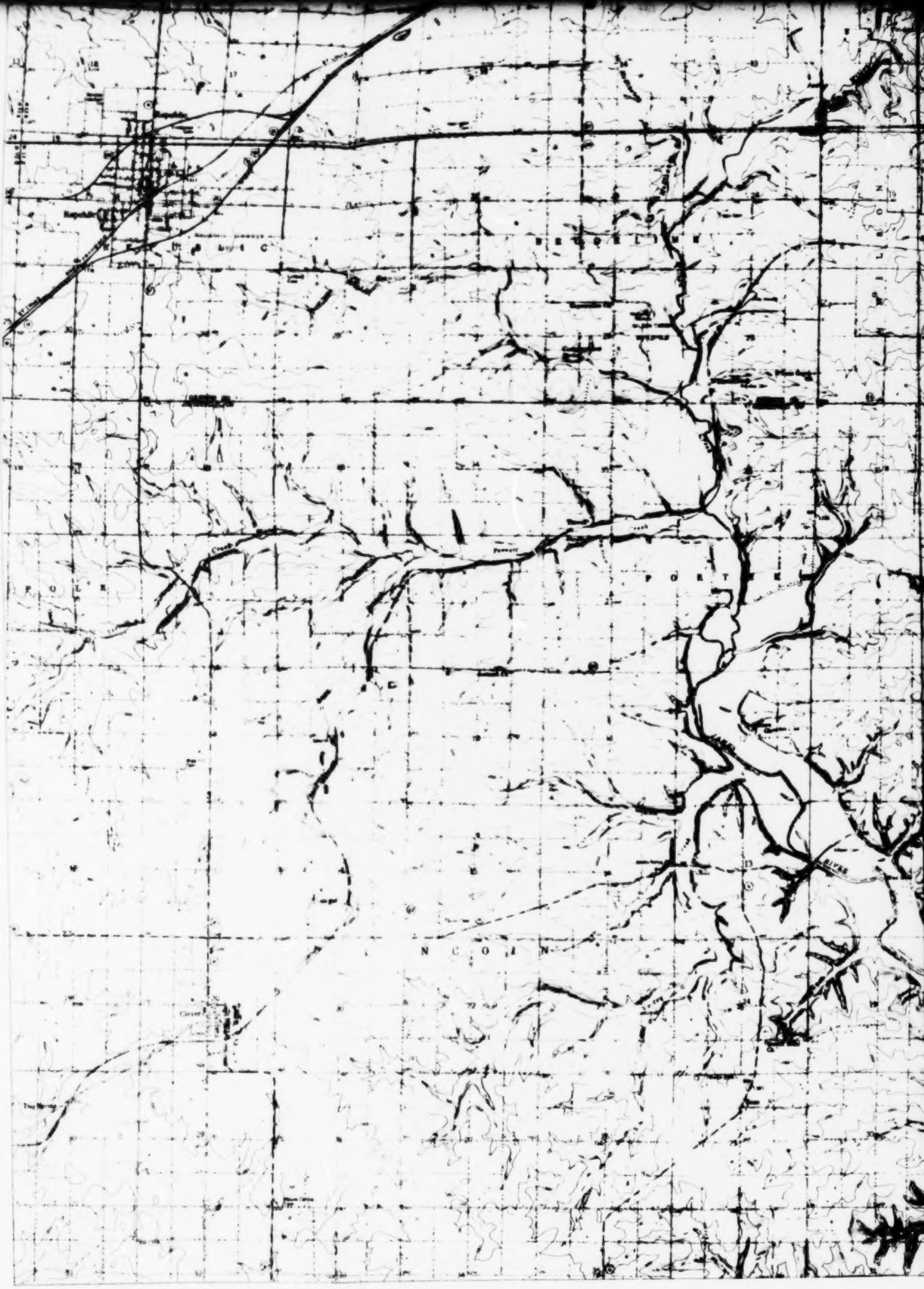
FIGURE 16

D



B


N O R T H
W I L S O N
C L A Y
Lake Springfield


Republic
R E P U B L I C
P O L K
P O R T E R
N C O I N
Clever
RIVER

WILSON CREEK PROJECT
GREENE AND CHRISTIAN COUNTIES, MO.
MISSOURI GEOLOGICAL SURVEY AND WATER RESOURCES

INTERNAL. DRAINAGE MAP

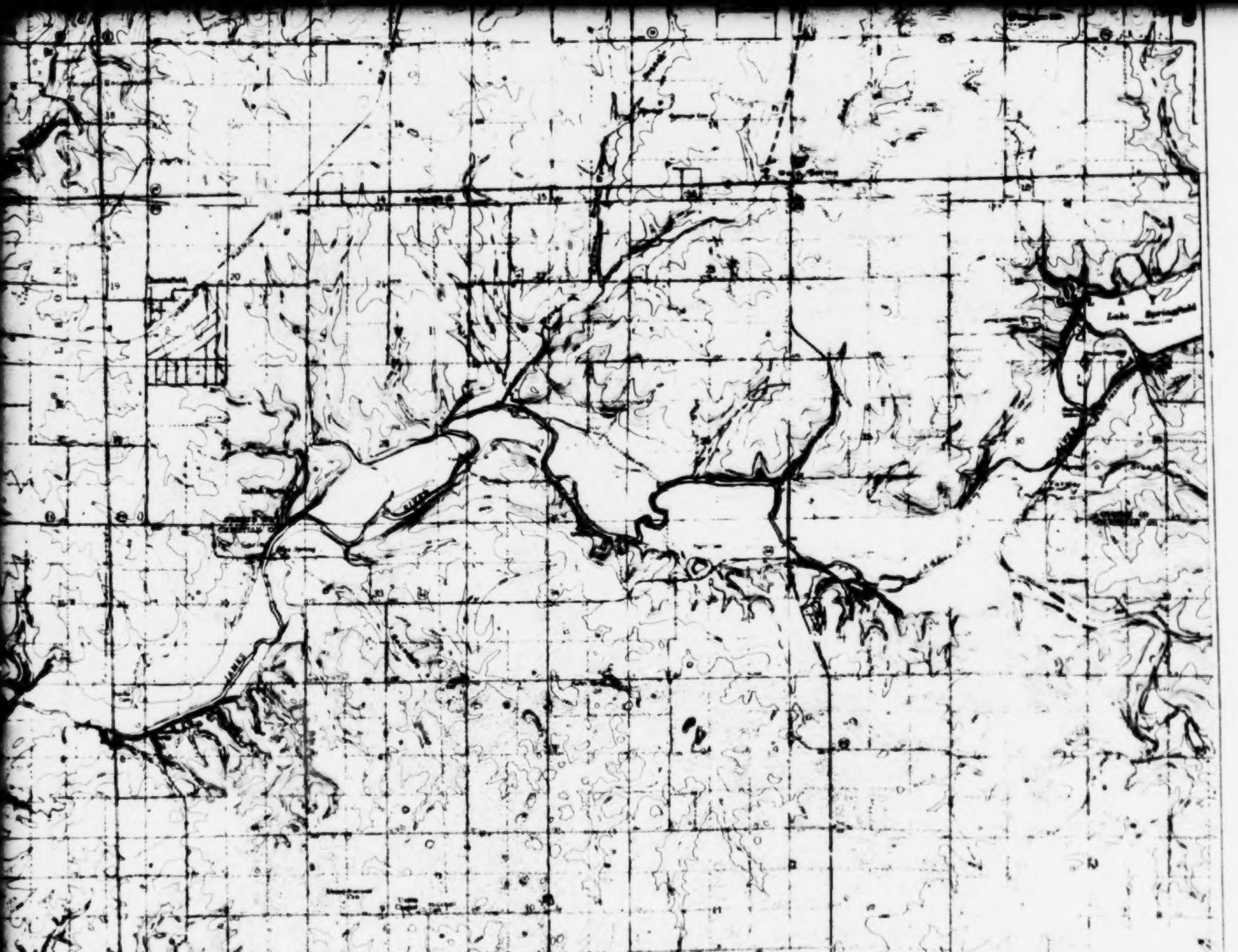
BY: JERRY D. VINEYARD
FOR FEDERAL WATER POLLUTION CONTROL AUTHORITY

SCALE	1:24,000	DECEMBER 1968

— — — dashed lines link injection sites with known resur
exact paths of travel are not inferred.

▨ Areas drained internally through sinks, sinkholes

C


Lake Springfield
PORTER
LINCOLN

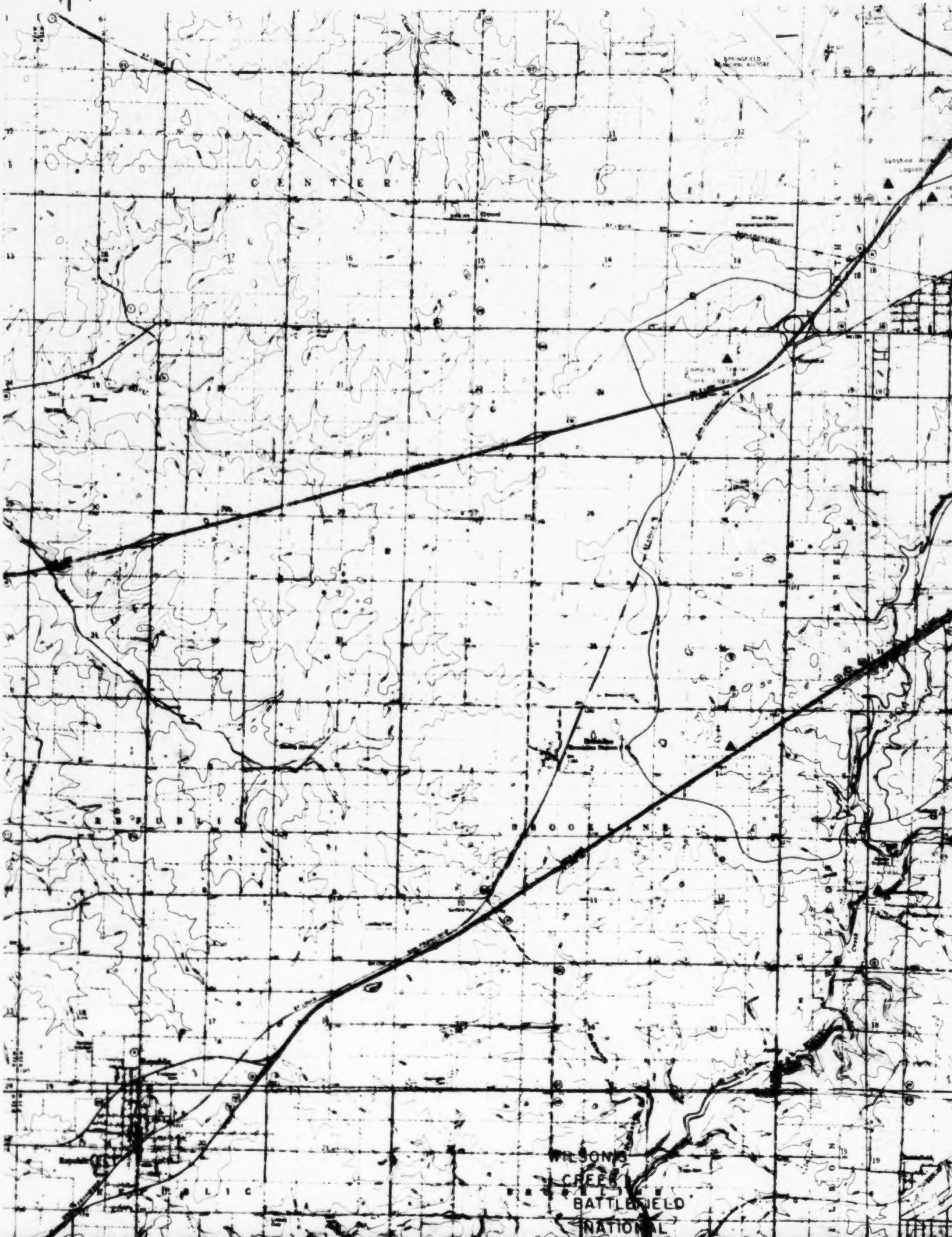
ith known resurgences (♂);
not inferred.

nks, sinkholes and swallow holes.

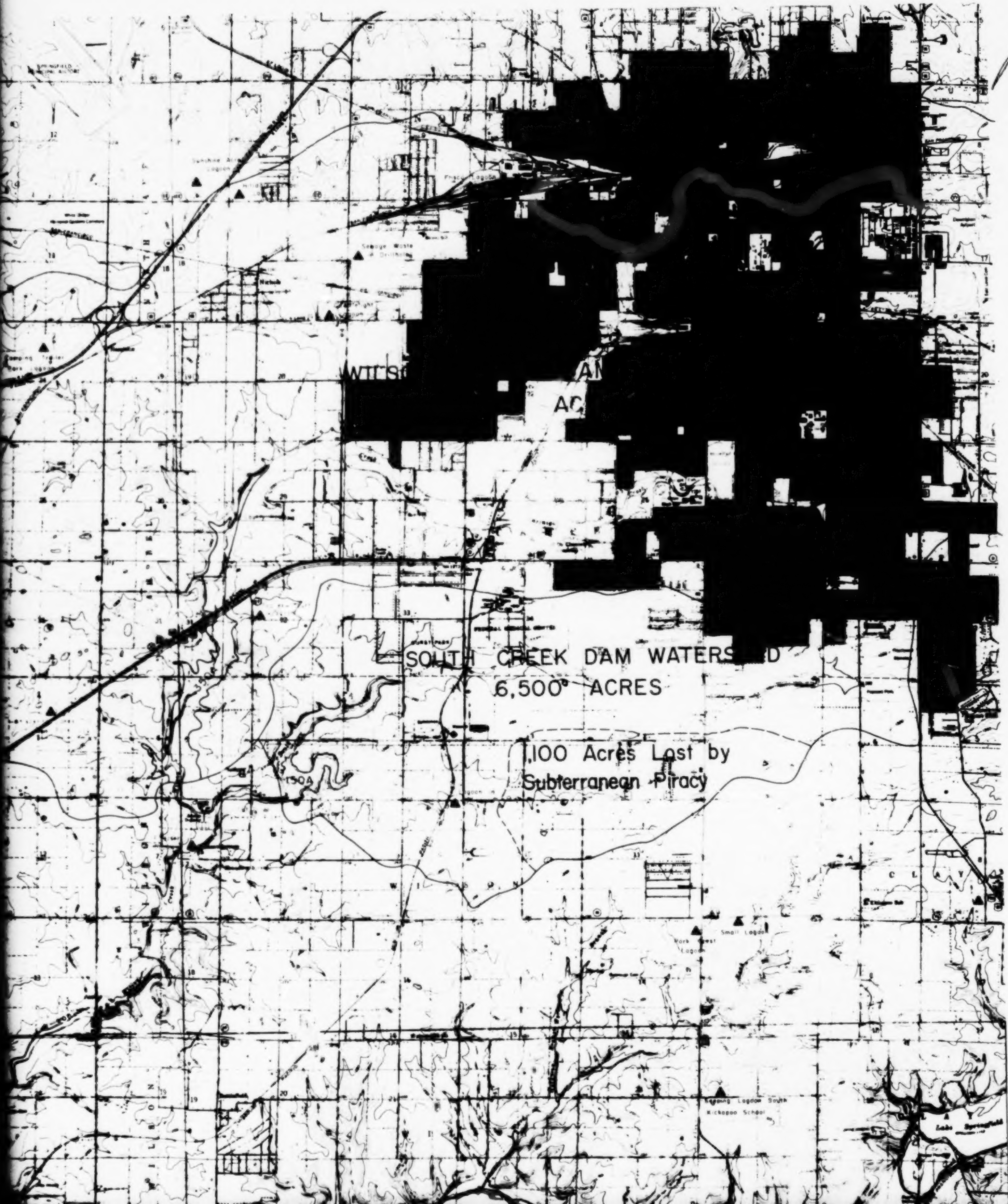
FIGURE 15

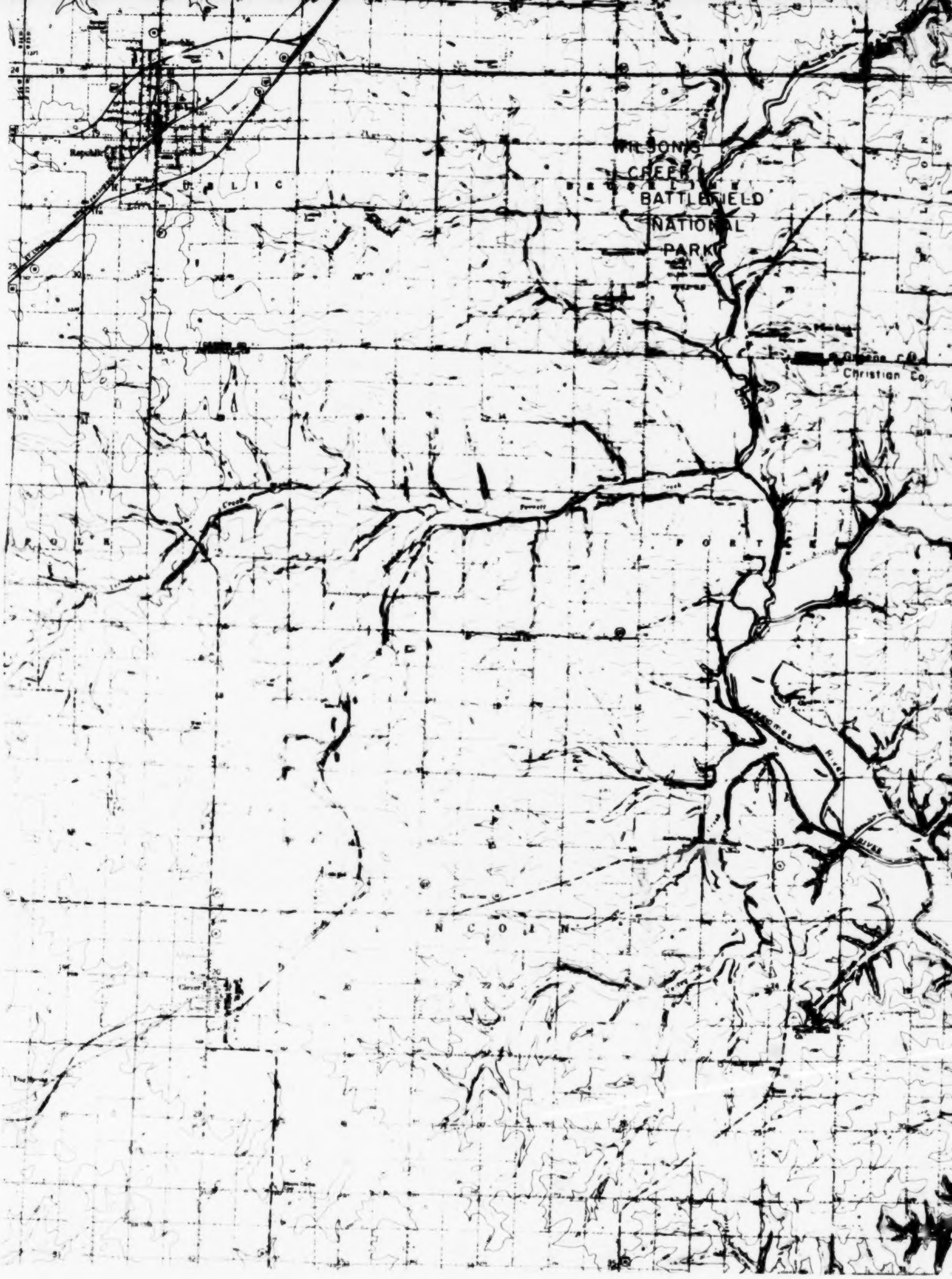
D

A



SPRINGFIELD MUNICIPAL AIRPORT
Sunshine Acres
CENTER
Camping Trailer
REPUBLIC
BROOKLINE
K
WILSON'S
CREEK
BATTLEFIELD
NATIONAL


SOUTH CREEK DAM WATERSHED
6,500 ACRES
1,100 Acres Lost by
Subterranean Piracy
AC
Small Lagoon
Park West Lagoon
C L A Y
Lake Springfield


WILSON'S CREEK BATTLEFIELD NATIONAL PARK
Republic
REPUBLIC
Greene Co.
Christian Co.
POLK
PORTER
LINCOLN
Clever

WILSON CREEK PROJECT
GREENE COUNTY, MO
MISSOURI GEOLOGICAL SURVEY AND WATER RESOURCES

Overlay For Brookline, Nixa, Republic, and Springfield Quadrangles
Showing Watersheds, Lagoons and Associated Features

BY: J. HADLEY WILLIAMS AND JERRY D. VINEYARD
FOR FEDERAL WATER POLLUTION CONTROL AUTHORITY

SCALE 1:24,000	JUNE 1968

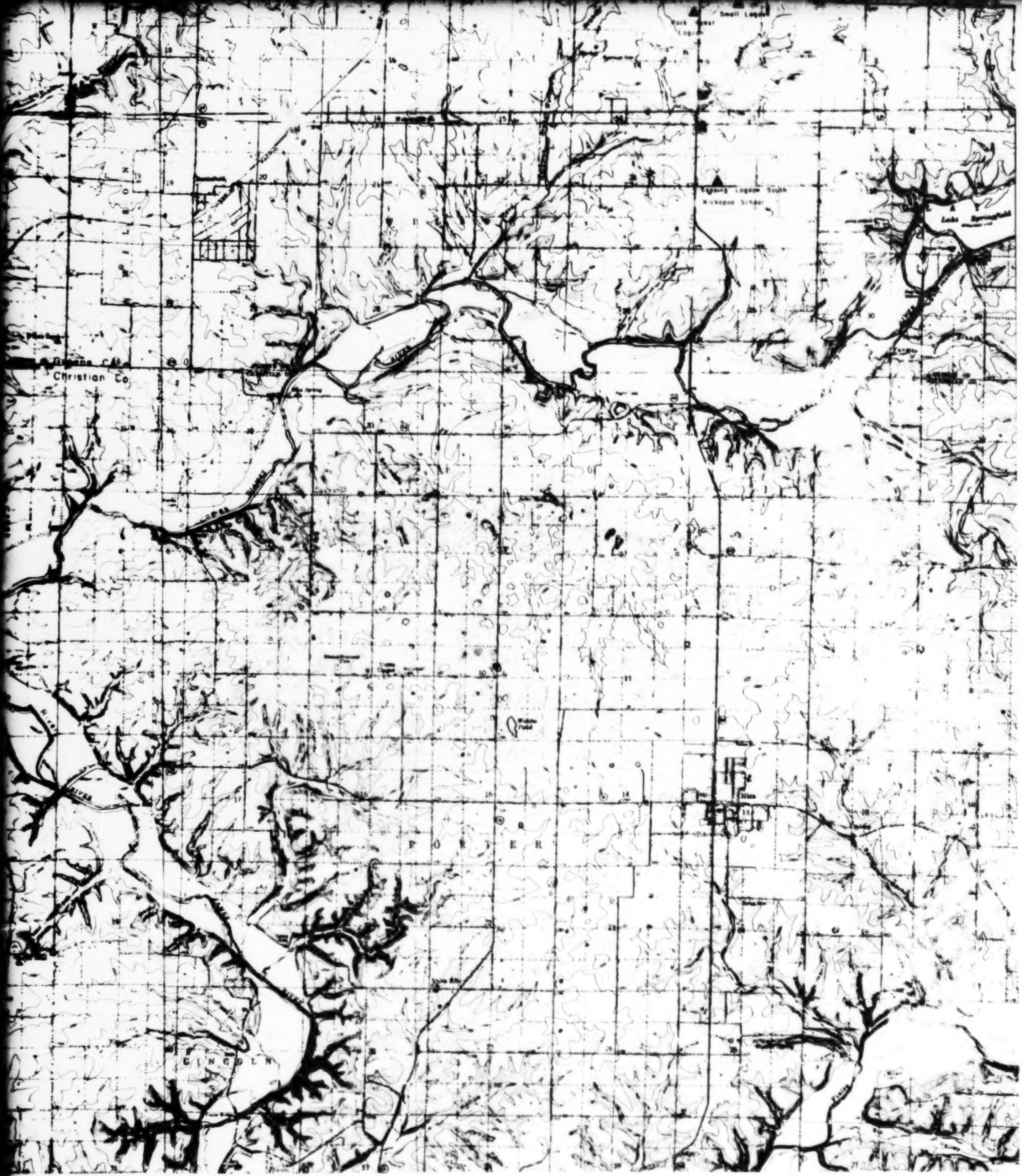
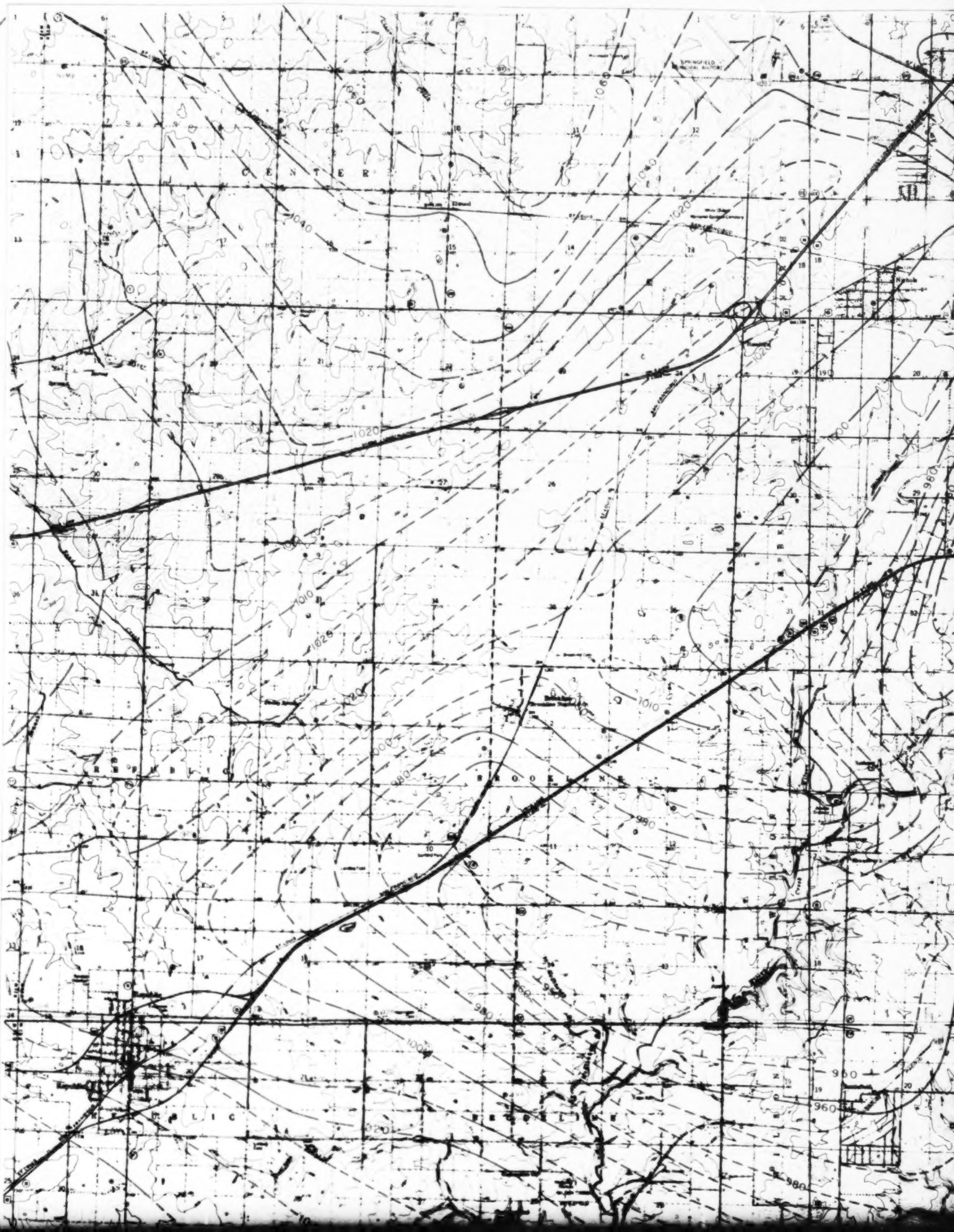
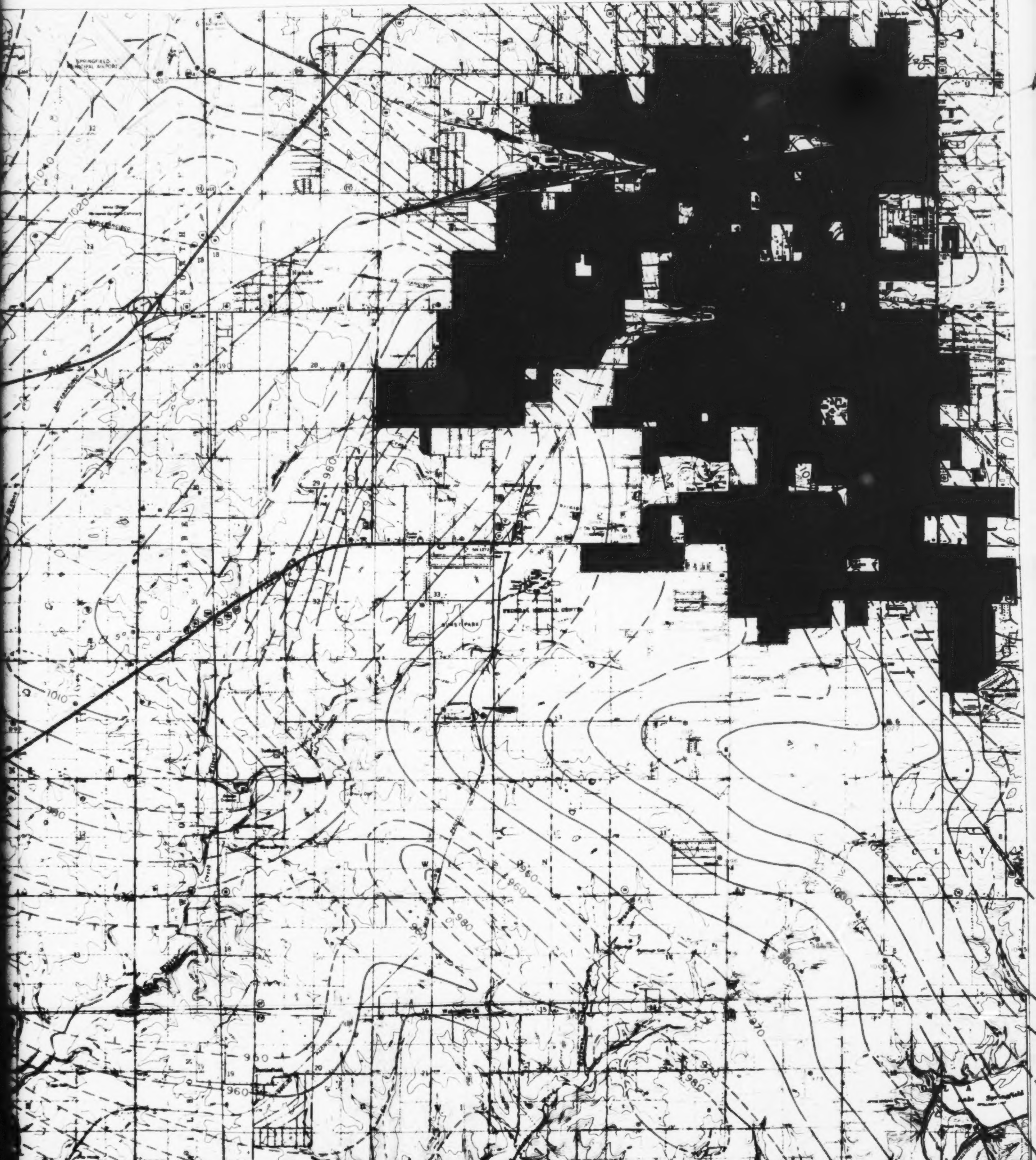
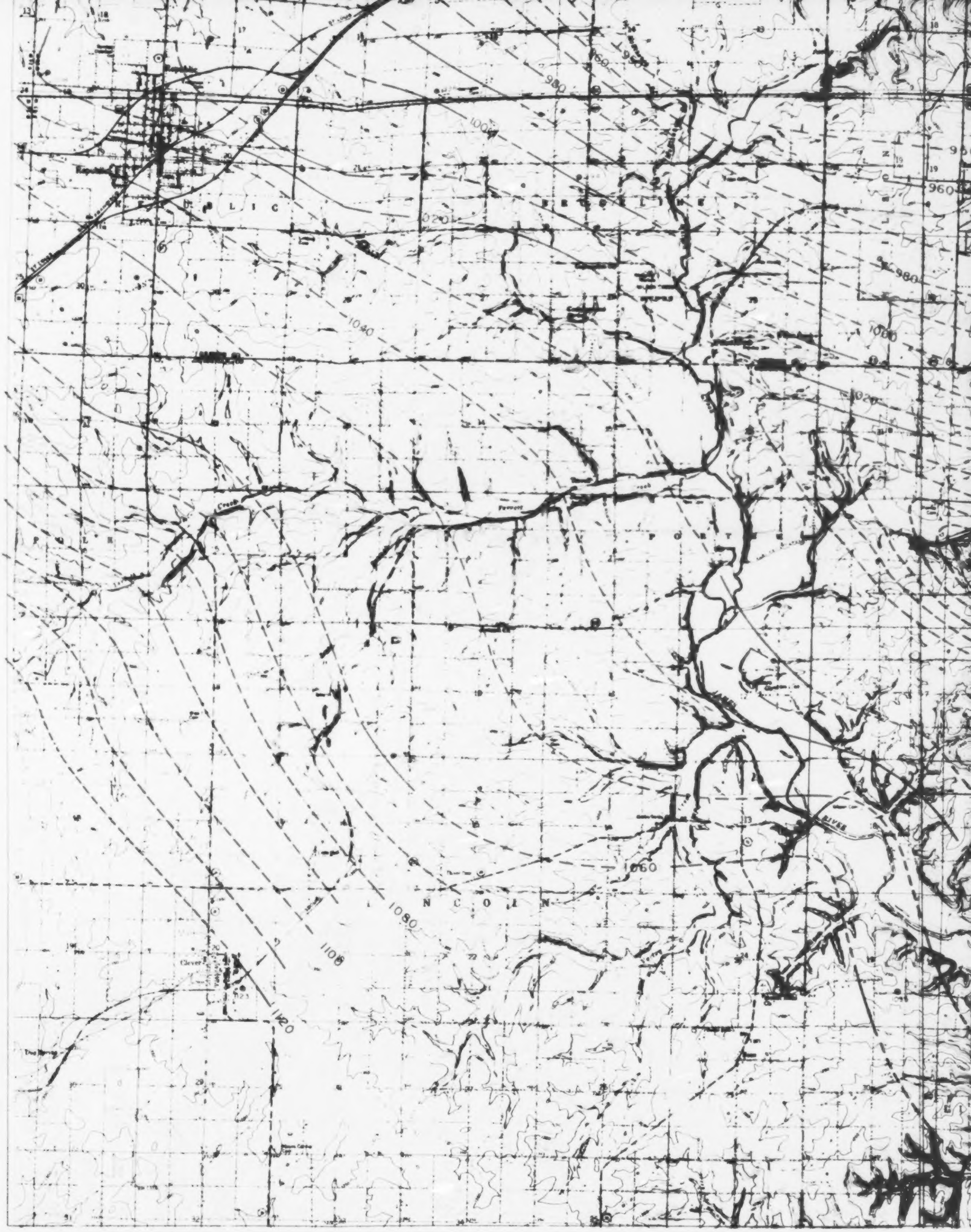

Small Logan
Kickapoo School
Lake Springfield
Christian Co.
PORTER
Nixa
LINCOLN

FIGURE 14

P


CENTER
SPRINGFIELD MUNICIPAL AIRPORT
1060
1040
1020
1010
1000
980
960
BROOKLINE

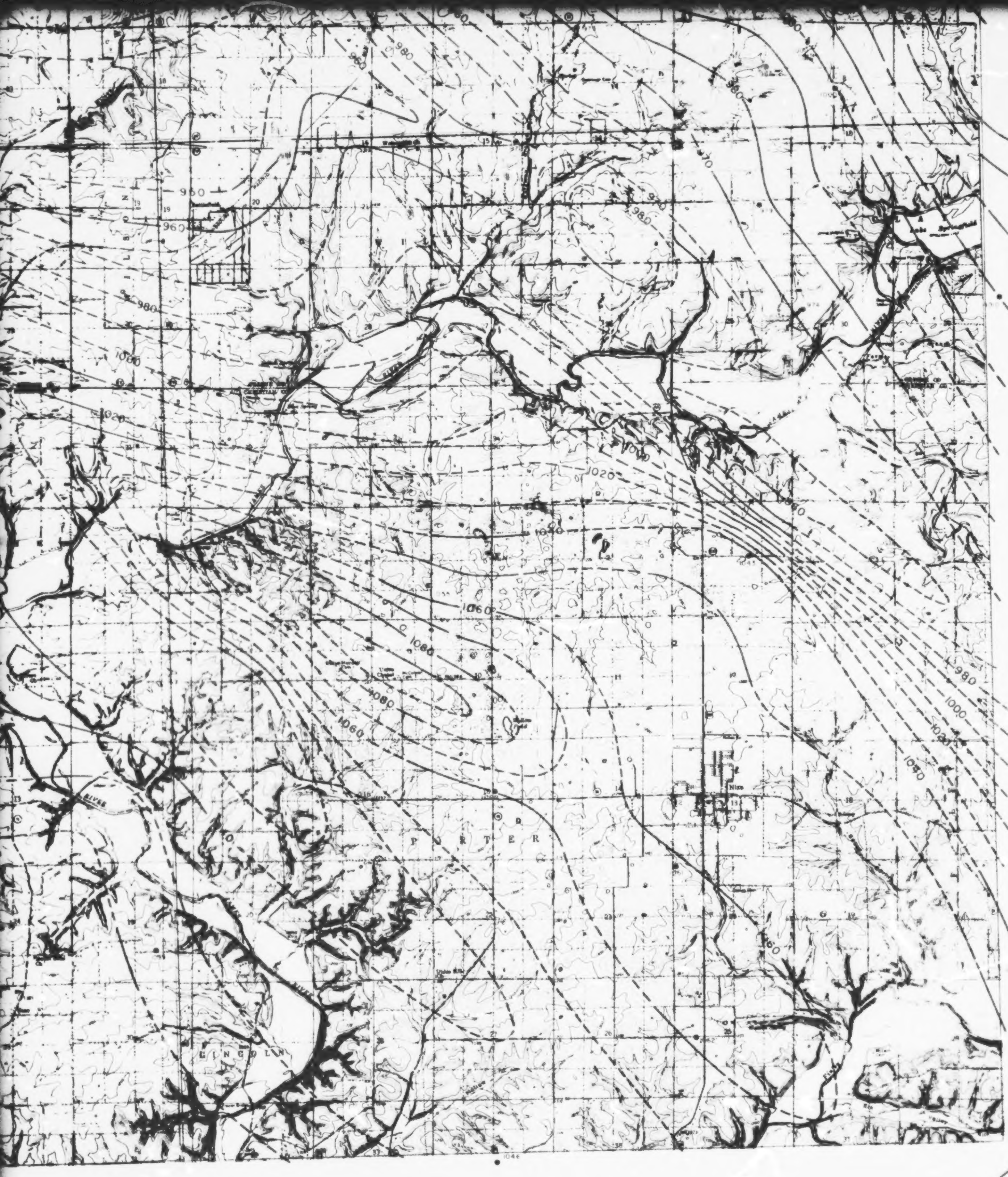

SPRINGFIELD MUNICIPAL AIRPORT
1040
1020
1010
980
960
970
C L A Y


960
980
1000
1020
1040
960
980
1000
1020
1060
1080
1100
1120
Clever

WILSON CREEK PROJECT
GREENE AND CHRISTIAN COUNTIES, MO.
MISSOURI GEOLOGICAL SURVEY AND WATER RESOURCES

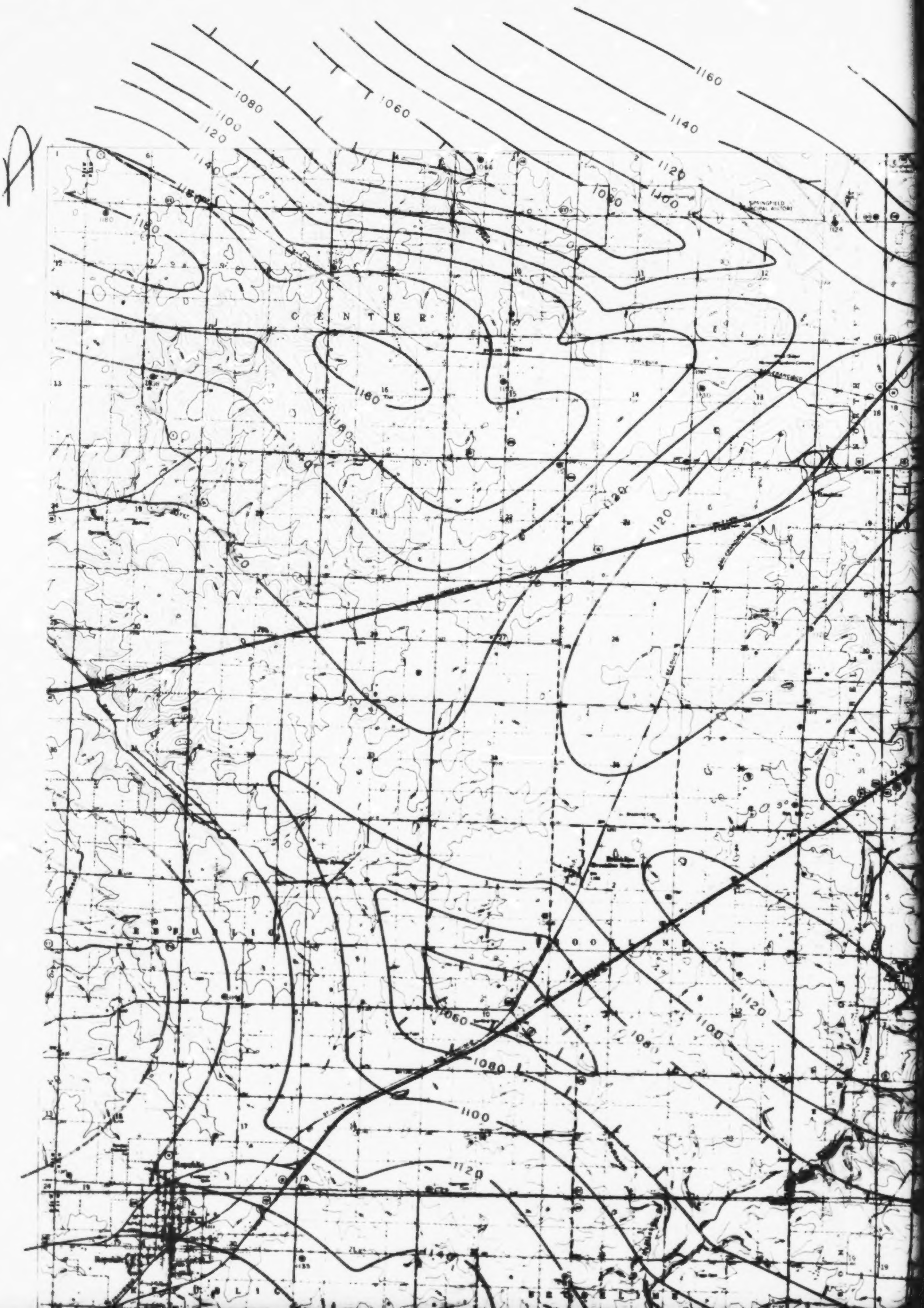
STRUCTURE CONTOUR MAP
DATUM: NORTHVIEW-PIERSON CONTACT
CONTOUR INTERVAL: 10 FEET
BY: L. D. FELLOWS
FOR FEDERAL WATER POLLUTION CONTROL AUTHORITY

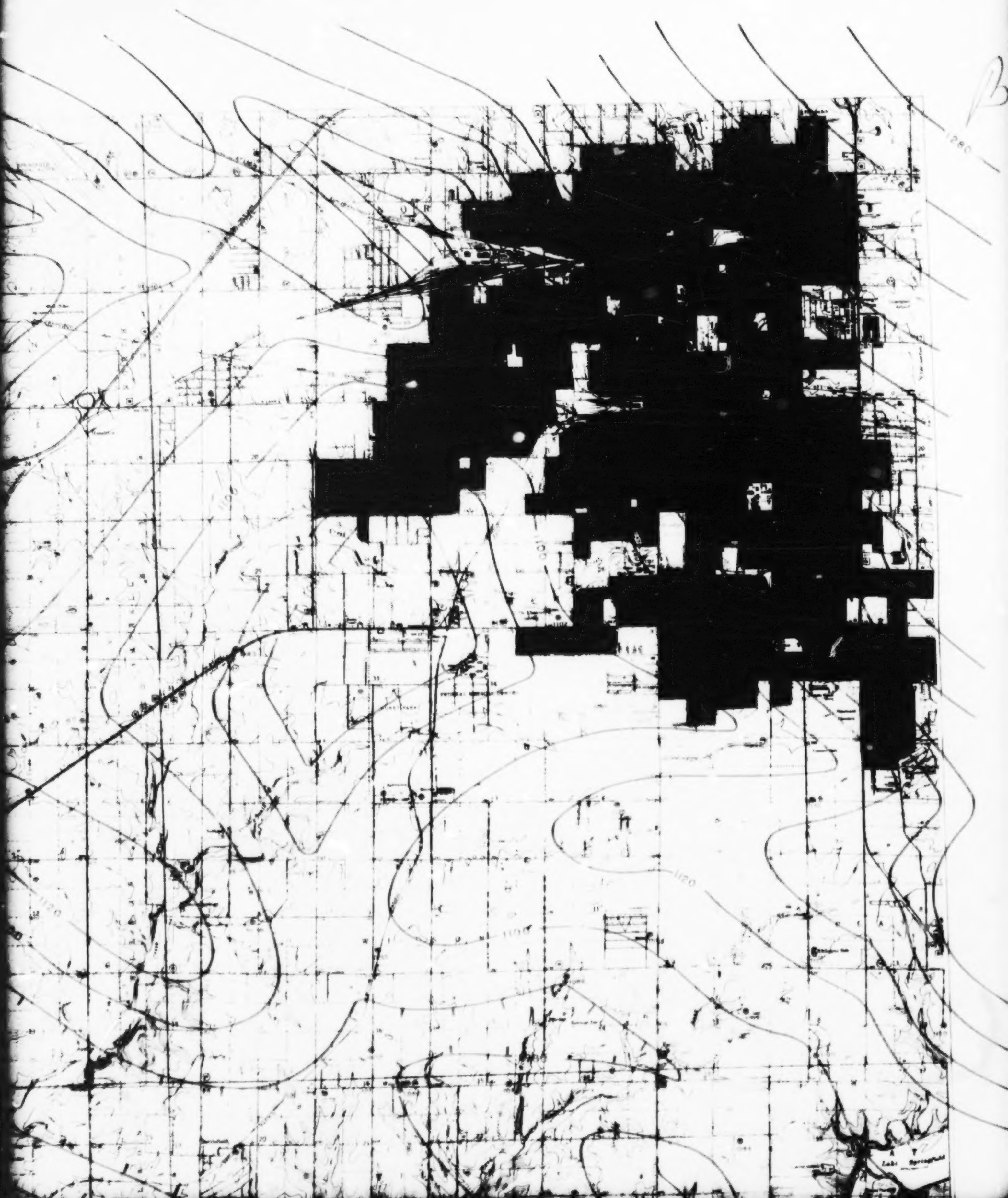
SCALE	1:24.000	JUNE 1968

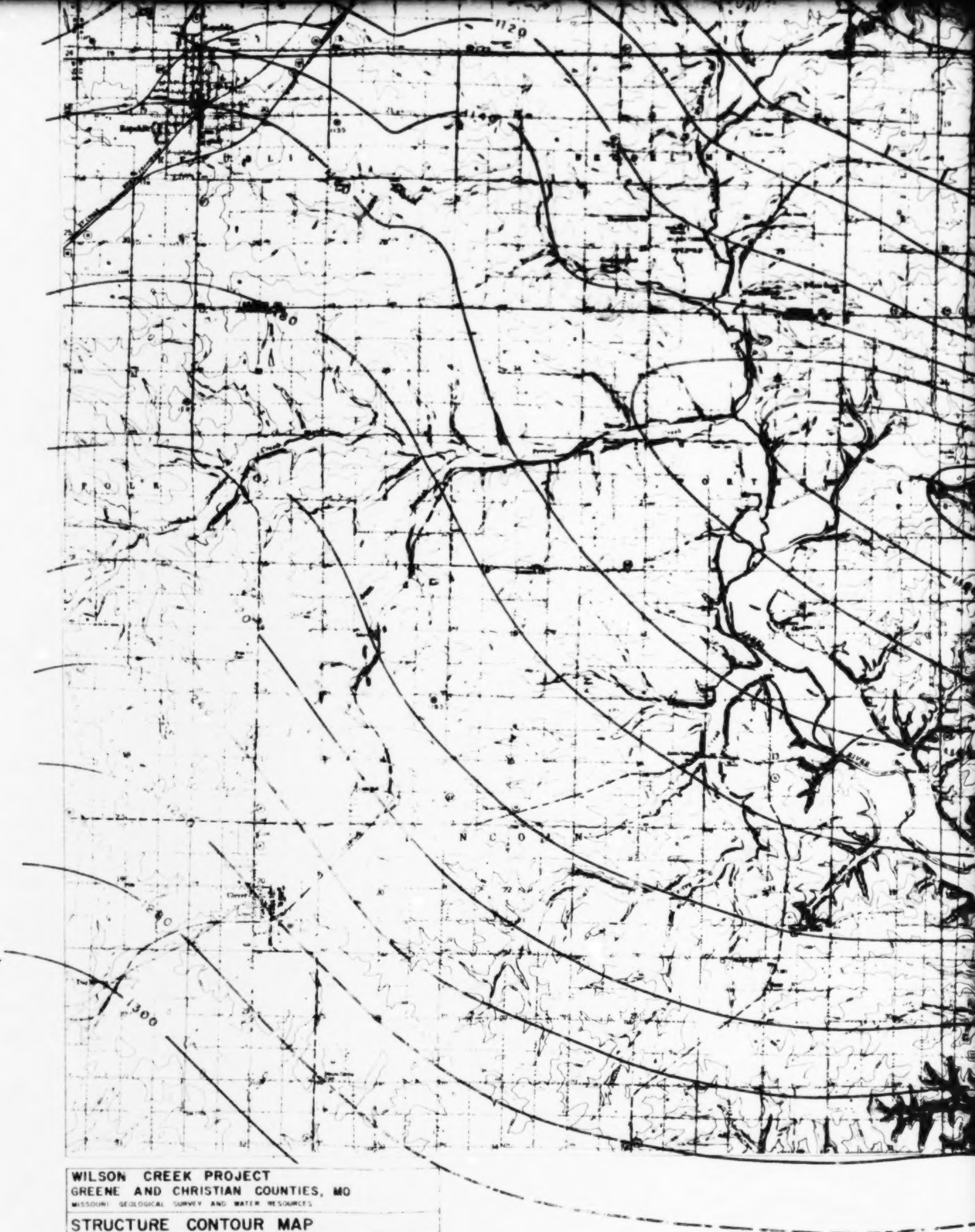

980
960
960
980
1000
1020
1020
1040
1060
1080
1080
1060
1000
980
1000
1020
1040
1060
PORTER
LINCOLN
Nixa

D

FIGURE 13


A
1160
1140
1080
1060
1100
1120
1140
1160
1180
1120
1080
1100
SPRINGFIELD MUNICIPAL AIRPORT
CENTER
1160
1180
1120
1120
1120
1100
1080
1060
1080
1100
1120


B
1280
1100
1100
1120
1120
1100
Lake Springfield


1120
1140
1180
1280
1300
P O L K
N C O L N

WILSON CREEK PROJECT
GREENE AND CHRISTIAN COUNTIES, MO
MISSOURI GEOLOGICAL SURVEY AND WATER RESOURCES

STRUCTURE CONTOUR MAP
DATUM: BASE OF BURLINGTON LIMESTONE
CONTOUR INTERVAL: 20 FEET
BY: L. D. FELLOWS
FOR FEDERAL WATER POLLUTION CONTROL AUTHORITY

SCALE	1:24,000	JUNE 1968

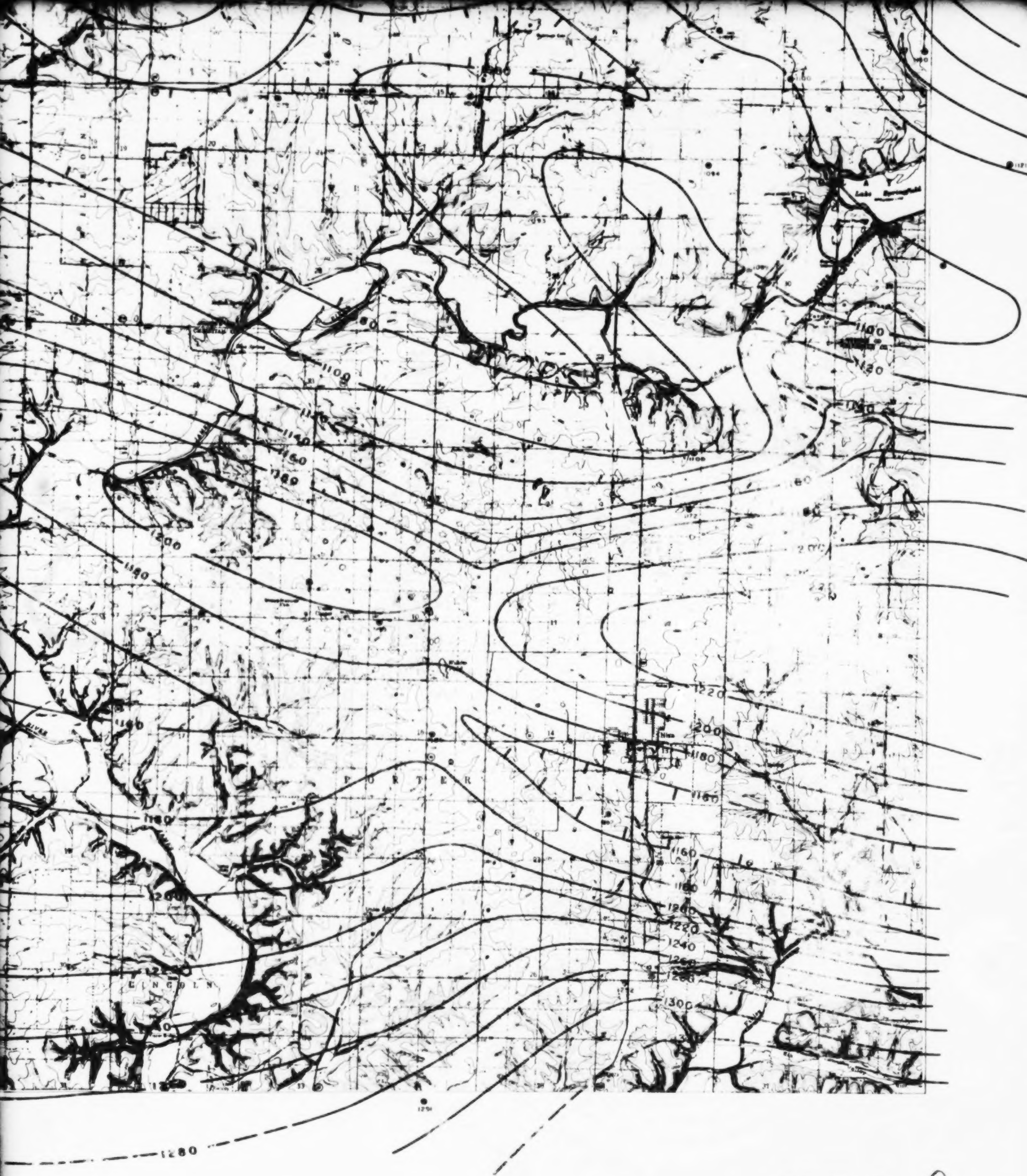

1100
1120
1140
1160
1180
1200
1220
1240
1260
1280
1300
PORTER
LINCOLN
Lake Springfield

FIGURE 12

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PHYSICAL AND CHEMICAL DATA - GROUNDWATE

Code No.	Well Owner	Well Depth (feet)	Well Location	Date	Temp. °C	p
1-54	Ozark Farm	91	29N-21W-29-cccl	5-23-68	19.5	7.
1-12	E. M. Roupe	270	28N-21W-7-dcdl	5-23-68	16.0	5.
1-88	Stout	190	29N-22W-21-cbal	5-23-68	14.0	-
1-84A	Barton		29N-22W-21-ccal	5-23-68	16.0	-
1-80	W. Bilyeu	165	29N-22W-19-bcdl	5-23-68	14.0	7.
0-120A	Kleir		29N-22W-21-adbl	5-23-68	16.0	-
0-124A	E. Roberts	100	29N-22W-29-cdcl	5-23-68	14.5	-
1-93	L. Moonyhan	1[illegible]	29N-22W-32-bcal	5-23-68	14.5	-
1-91	H. Hazeltine	130	29N-22W-31-adcl	5-23-68	17.0	5.
0-19	Riley	172	28N-22W-6-bbbl	5-23-68	13.0	7.
1-30A	Mrs. Ethel Hudson	70	28N-22W-2-adal	5-23-68	17.0	6.
1-35	B. Banta	128	28N-22W-17-aabl	5-23-68	13.5	5.
	Wilson Creek @ Rader Bridge		28N-22W-18-bda	5-23-68	20.5	7.
	Rader Spring		28N-22W-18-bdc	5-23-68	15.0	6.
1-36	J. Hampton	290	28N-22W-20-cbcl	5-22-68	13.0	8.
1-38	M. Fenley	155	28N-22W-23-ada2	5-22-68	12.0	8.
1-41	J. Johnson	160	28N-23W-15-accl	5-23-68	14.5	7.
1-40	Edgar Green	223	28N-23W-15-cdal	5-23-68	14.5	7.
1-42	A. Rankin	90	28N-23W-15-cccl	5-23-68	13.5	7.
1-43	W. McConnell	266	28N-23W-27-aaal	5-23-68	14.5	7.
	Spring on Virgil Cox's farm		27N-23W-1-bdc	5-23-68	12.5	7.
1-2A	Eugene J. Hall		27N-22W-3-bddl	5-22-68	12.0	8.
1-1	F. E. Weddington	175	27N-22W-2-aaal	5-22-68	13.0	8.
1-5A	Frazier	20	27N-22W-29-bbal	5-22-68	11.5	8.
0-1A	Ed Richmond	185	27N-21W-19-bccl	5-22-68	12.0	8.

TABLE 1

CHEMICAL DATA - GROUNDWATER QUALITY SURVEY

Date	Temp. °C	pH	Cond. µmhos/cm	Org.N mg/1	NH_3-N mg/1	NO_2-N mg/1	NO_3-N mg/1	SO_4 mg/1	PO_4-P mg/1
5-23-68	19.5	7.0	700	0.3	< 0.1	0.22	1.18	42	.65
5-23-68	16.0	5.9	530	0.2	< 0.1	0.01	.09	31	.77
5-23-68	14.0	-	580	0.2	< 0.1	0.08	2.42	18	0.90
5-23-68	16.0	-	560	0.2	< 0.1	0.08	9.92	9	0.84
5-23-68	14.0	7.7	400	0.2	< 0.1	0.01	6.59	3	.77
5-23-68	16.0	-	350	0.2	< 0.1	0.08	0.12	16	0.97
5-23-68	14.5	-	500	0.2	< 0.1	0.01	5.59	5	1.10
5-23-68	14.5	-	640	0.2	< 0.1	0.01	3.39	5	1.03
5-23-68	17.0	5.1	540	0.2	0.10	0.01	3.39	11	1.10
5-23-68	13.0	7.7	375	0.2	< 0.1	0.02	4.58	3	.84
5-23-68	17.0	6.1	350	0.2	< 0.1	0.01	4.99	10	.90
5-23-68	13.5	5.4	450	0.2	< 0.1	0.01	3.39	9	.77
5-23-68	20.5	7.4	750	6.86	1.14	0.06	0.14	45	7.70
5-23-68	15.0	6.9	560	2.55	0.25	0.10	2.50	20	3.48
5-22-68	13.0	8.35	515	0.2	< 0.1	0.01	.09	19	.78
5-22-68	12.0	8.30	425	0.4	< 0.1	0.01	2.79	7	1.06
5-23-68	14.5	7.3	510	0.2	< 0.1	0.01	9.99	3	.90
5-23-68	14.5	7.4	760	0.2	< 0.1	0.01	31.49	10	1.09
5-23-68	13.5	7.45	460	0.2	< 0.1	0.01	.09	5	.84
5-23-68	14.5	7.45	750	0.3	< 0.1	0.06	28.74	37	1.03
5-23-68	12.5	7.9	410	0.5	< 0.1	0.02	3.78	9	1.16
5-22-68	12.0	8.5	690	0.04	0.16	0.01	14.39	7	0.97
5-22-68	13.0	8.25	610	0.3	< 0.1	0.01	6.19	52	1.19
5-22-68	11.5	8.95	570	0.4	0.2	0.01	31.99	13	0.97
5-22-68	12.0	8.85	800	0.2	0.1	0.01	16.79	13	1.03

B

PHYSICAL AND CHEMICAL DATA — GROUN

Code No.	Owner	Well Depth (feet)	Well Location	Date	Temp. °C	pH
1-54	Ozark Farm	91	29N-21W-29-ccc1	6-7-68	21.0	6.7
4-55	W. G. Challacombe	165	29N-22W-16-bca1	6-6-68	18.0	6.8
4-56	C. Draelants	98	29N-22W-16-bcc1	6-6-68	16.0	6.4
4-54	C. Stokes	50	29N-22W-17-cbd1	6-6-68	17.0	6.5
4-53	B. Grisham	35	29N-22W-18-dda1	6-6-68	16.0	6.5
1-80	W. Bilyeu	165	29N-22W-19-bcd1	6-7-68	17.0	6.1
1-81	J. Tuckness	184	29N-22W-19-dbb1	6-6-68	21.0	7.0
1-88	Stout	190	29N-22W-21-cba1	6-6-68	20.0	7.6
4-50	R. L. Patrick	75	29N-22W-26-cab1	6-6-68	15.0	6.7
4-36	King		29N-22W-27-bba1	6-6-68	16.0	6.8
4-57	P. Ramsey	120	29N-22W-27-bcd1	6-6-68	20.0	6.8
4-35	Kilburn	100	29N-22W-28-aad1	6-6-68	16.0	6.5
0-124A	E. Roberts	100	29N-22W-29-cdc1	6-6-68	19.0	6.1
0-120A	Kleir		29N-22W-29-adb1	6-6-68	18.0	6.7
1-91	H. Hazeltine	130	29N-22W-31-adc1	6-6-68	20.0	6.8
1-93	L. Moonyhan	120	29N-22W-32-bca1	6-6-68	18.0	6.6
4-39	L. Hill	75	28N-23W-14-bcd1	6-6-68	18.0	
1-41	J. Johnson	160	28N-23W-15-acc1	6-6-68	15.0	
1-42	A. Rankin	90	28N-23W-15-ccc1	6-6-68	16.0	
1-40	E. Green	223	28N-23W-15-cda1	6-6-68	16.0	
4-43	C. Hampton	80	28N-23W-24-cbb1	6-6-68		
4-45	Battlefield Park — U. S. Government	220	28N-23W-26-dbc1	6-6-68	14.0	
1-43	W. McConnell	266	28N-23W-27-aaa1	6-6-68	20.0	
4-48	J. W. Fuggitt	40	28N-23W-35-dcb1	6-6-68	17.0	
4-47	G. Hancock	106	28N-23W-36-ccc1	6-6-68	15.0	
	Spring on Virgil Cox's farm		27N-23W-1-bdc	6-6-68	15.0	
1-30A	E. Hudson	70	28N-22W-1-ada1	6-5-68	19.0	6.7
1-32	H. Cooper	107	28N-22W-7-daa1	6-5-68	19.0	6.2

TABLE 2

YSICAL AND CHEMICAL DATA - GROUNDWATER QUALITY SURVEY

	Date	Temp. °C	pH	Cond. µmhos/cm	Org.N mg/1	NH_3-N mg/1	NO_2-N mg/1	NO_3-N mg/1	SO_4 mg/1	PO_4-P mg/1	TOC mg/1
1	6-7-68	23.0	6.7	600	.30	< 0.1	.17	1.9	39	1.00	4.2
1	6-6-68	18.0	6.8	480	.30	< 0.1	< .02	5.2	11	.90	6.7
1	6-6-68	16.0	6.4	700	.10	< 0.1	< .02	6.0	45	.86	5.3
1	6-6-68	17.0	6.5	650	.20	< 0.1	< .02	4.3	106	.77	5.6
1	6-6-68	16.0	6.5	690	.60	< 0.1	< .02	4.2	16	.62	7.5
1	6-7-68	17.0	6.3	460	< .1	< 0.1	< .02	7.8	5	.66	4.2
1	6-6-68	21.0	7.0	460	.33	< 0.1	< .02	5.4	11	.96	4.8
1	6-6-68	20.0	7.6	610	.10	< 0.1	< .02	2.3	21	.66	5.0
1	6-6-68	15.0	6.7	420	.92	.78	< .02	< .1	9	.47	6.6
1	6-6-68	16.0	6.8	580	.20	< 0.1	< .02	3.7	16	.90	6.5
1	6-6-68	20.0	6.8	500	.73	< 0.1	< .02	4.5	10	.86	5.8
1	6-6-68	16.0	6.5	470	.10	< 0.1	< .02	7.0	9	.85	5.8
1	6-6-68	19.0	6.3	470	.70	< 0.1	< .02	5.5	8	.71	5.3
1	6-6-68	18.0	6.7	360	.30	< 0.1	< .02	.4	17	.71	4.2
1	6-6-68	20.0	6.8	530	.56	< 0.1	< .02	3.5	13	.77	4.8
1	6-6-68	18.0	6.6	650	.60	< 0.1	< .02	3.9	5	1.00	3.8
1	6-6-68	18.0		640	.40	< 0.1	< .02	5.6	41	.72	5.1
c1	6-6-68	15.0		600	.10	< 0.1	< .02	6.8	5	.83	4.4
c1	6-6-68	16.0		560	.60	< 0.1	< .02	.5	10	.52	7.5
a1	6-6-68	16.0		760	.20	< 0.1	< .02	30.0	12	.52	5.3
b1	6-6-68				.10	< 0.1	< .02	21.0	38	2.02	6.5
c1	6-6-68	14.0		400	.10	< 0.1	< .02	1.4	9	.83	8.8
a1	6-6-68	20.0		750	.10	< 0.1	0.02	9.98	32	.68	7.3
b1	6-6-68	17.0		440	< .1	< 0.1	< .05	6.8	16	.72	6.7
c1	6-6-68	15.0		900	< .1	< 0.1	< .05	41.0	27	.72	8.3
	6-6-68	15.0		390	.30	< 0.1	< .05	3.9	7	.83	9.0
1	6-5-68	19.0	6.7	360	.10	< 0.1	< .02	5.1	11	.61	7.5
1	6-5-68	19.0	6.2	580	.10	< 0.1	< .05	4.3	15	.61	12.2

PHYSICAL AND CHEMICAL DATA - GROUNDWATER QUALIT

Code No.	Well Owner	Well Depth (feet)	Well Location	Date	Temp. °C	pH	Cond. μmhos/c
1-33A	R. Jackson		28N-22W-8-bdc1	6-5-68	15.0	6.7	390
4-24	Spring @ J. R. Campbell's farm		28N-22W-10-ddb	6-5-68	13.5	7.0	550
4-21	W. Rence	180	28N-22W-14-abb1	6-5-68	19.0	6.3	440
4-22	C. J. Green	72	28N-22W-15-abb1	6-5-68	15.0	6.8	775
1-34	B. Bass	248	28N-22W-16-aab1	6-5-68	25.0	6.5	520
1-35	B. Banta	128	28N-22W-17-aab1	6-5-68	16.0	7.1	480
4-42	C. Chastain	180	28N-22W-19-cbb1	6-6-68	20.0		460
1-36	J. Hampton	120	28N-22W-20-cbc1	6-4-68	15.0	6.4	510
1-37	R. L. Scott	162	28N-22W-21-aba1	6-4-68	21.0	6.4	340
1-38	M. Fenley	98	28N-22W-23-ada2	6-4-68	19.0	6.4	390
4-2	N. Patterson		28N-22W-24-dbb1	6-4-68	17.0	6.2	380
1-39	N. Maples		28N-22W-25-aaa1	6-4-68	21.0	6.2	420
4-7	P. J. Steinert	209	28N-22W-26-abc1	6-4-68	19.0	6.2	1200
4-6	J. P. Steinert	147	28N-22W-27-aad1	6-4-68	16.0	6.6	450
4-5	S. Williams	200	28N-22W-28-cbb1	6-4-68	19.0	6.3	450
4-4	O. Kothendeutel	210	28N-22W-29-bcc1	6-4-68	18.0	6.5	480
4-12	C. H. Blades	200	28N-22W-32-dad1	6-5-68	17.0	5.9	400
4-11	McMeese	200	28N-22W-33-acc1	6-5-68	14.0	5.9	1050
4-10	J. C. McDaniel	100	28N-22W-34-bdd1	6-5-68	19.0	6.3	490
4-9	A. Eoff	103	28N-22W-35-acb1	6-5-68	18.0	6.4	470
4-8	Nevatte	100	28N-22W-36-bbc1	6-5-68	14.0	6.1	400
1-1	F. E. Weddington	175	27N-22W-2-aaa1	6-5-68	17.0		600
4-14	G. Sanders	200	27N-22W-4-bda1	6-5-68	17.0		540
4-13	K. Lawson	110	27N-22W-5-cba1	6-5-68	14.0	2.9	720
4-17	R. Rogers	145	27N-22W-8-caa1	6-5-68	20.0	5.6	620
4-16	E. Ginger	112	27N-22W-9-ddd1	6-5-68	17.0		500
1-3	E. T. Pope	131	27N-22W-10-cbb1	6-5-68	19.0		550
1-12	E. M. Roupe	270	28N-21W-7-dcd1	6-5-68	15.0	6.7	580
4-1	J. Norris		28N-21W-19-bcb1	6-4-68	17.0	6.0	750

157<

TABLE 2

HEMICAL DATA - GROUNDWATER QUALITY SURVEY (Continued)

Date	Temp. °C	pH	Cond. µmhos/cm	Org.N. mg/1	NH_3-N mg/1	NO_2-N mg/1	NO_3-N mg/1	SO_4 mg/1	PO_4-P mg/1	TOC mg/1
-5-68	15.0	6.7	390	< .1	< 0.1	.04	2.96	14	.61	6.6
-5-68	13.5	7.0	550	.40	< 0.1	< .05	18.4	8	.72	8.4
-5-68	19.0	6.3	440	.10	< 0.1	< .05	1.9	8	.68	6.6
6-5-68	15.0	6.8	775	.30	< 0.1	< .05	26.0	7	.68	8.3
6-5-68	25.0	6.5	520	.10	< 0.1	< .05	9.2	4	.83	10.5
6-5-68	16.0	7.1	480	.30	< 0.1	< .05	4.1	6	.52	7.5
6-6-68	20.0		460	.10	< 0.1	< .02	2.4	11	.61	6.6
6-4-68	15.0	6.4	510	.40	< 0.1	.08	.02	15	.52	8.9
6-4-68	21.0	6.4	340	< .1	< 0.1	< .05	4.4	4	.61	9.0
6-4-68	19.0	6.4	390	.44	.26	< .05	1.0	3	.90	11.9
6-4-68	17.0	6.2	380	< .1	< 0.1	< .05	4.6	3	.68	9.0
6-4-68	21.0	6.2	420	< .1	< 0.1	< .05	6.0	3	.90	8.2
6-4-68	19.0	6.2	1200	.49	.81	< .05	13.0	21	.78	6.9
6-4-68	16.0	6.6	450	.5	< 0.1	< .05	1.3	41	.78	6.9
6-4-68	19.0	6.3	450	.1	< 0.1	< .05	3.8	20	.68	4.7
6-4-68	18.0	6.5	480	.20	< 0.1	< .05	5.6	21	.72	8.4
6-5-68	17.0	5.9	400	.1	< 0.1	< .05	.8	14	.68	5.3
6-5-68	14.0	5.9	1050	1.60	6.5	< .05	.2	36	.15	462.0
6-5-68	19.0	6.3	490	< .1	< 0.1	< .05	7.0	3	.61	4.8
6-5-68	18.0	6.4	470	.10	< 0.1	< .05	5.1	7	.72	6.0
6-5-68	14.0	6.1	400	.10	< 0.1	< .05	3.0	4	.78	4.8
6-5-68	17.0		600	< .1	< 0.1	< .05	3.5	45	.78	7.7
6-5-68	17.0		540	.20	< 0.1	< .05	6.6	< 1	.72	8.2
6-5-68	14.0	2.9	720	.40	< 0.1	< .05	2.4	16	.94	9.6
6-5-68	20.0	5.6	620	< .1	0.18	< .05	4.9	10	.72	4.8
6-5-68	17.0		500	.40	< 0.1	< .05	2.2	< 1	.90	13.5
6-5-68	19.0		550	.20	< 0.1	< .05	3.4	< 1	.78	8.4
6-5-68	15.0	6.7	580	.20	< 0.1	< .05	.3	34	.61	6.6
6-4-68	17.0	6.0	750	< .1	< 0.1	< .05	10.0	7	.78	9.8

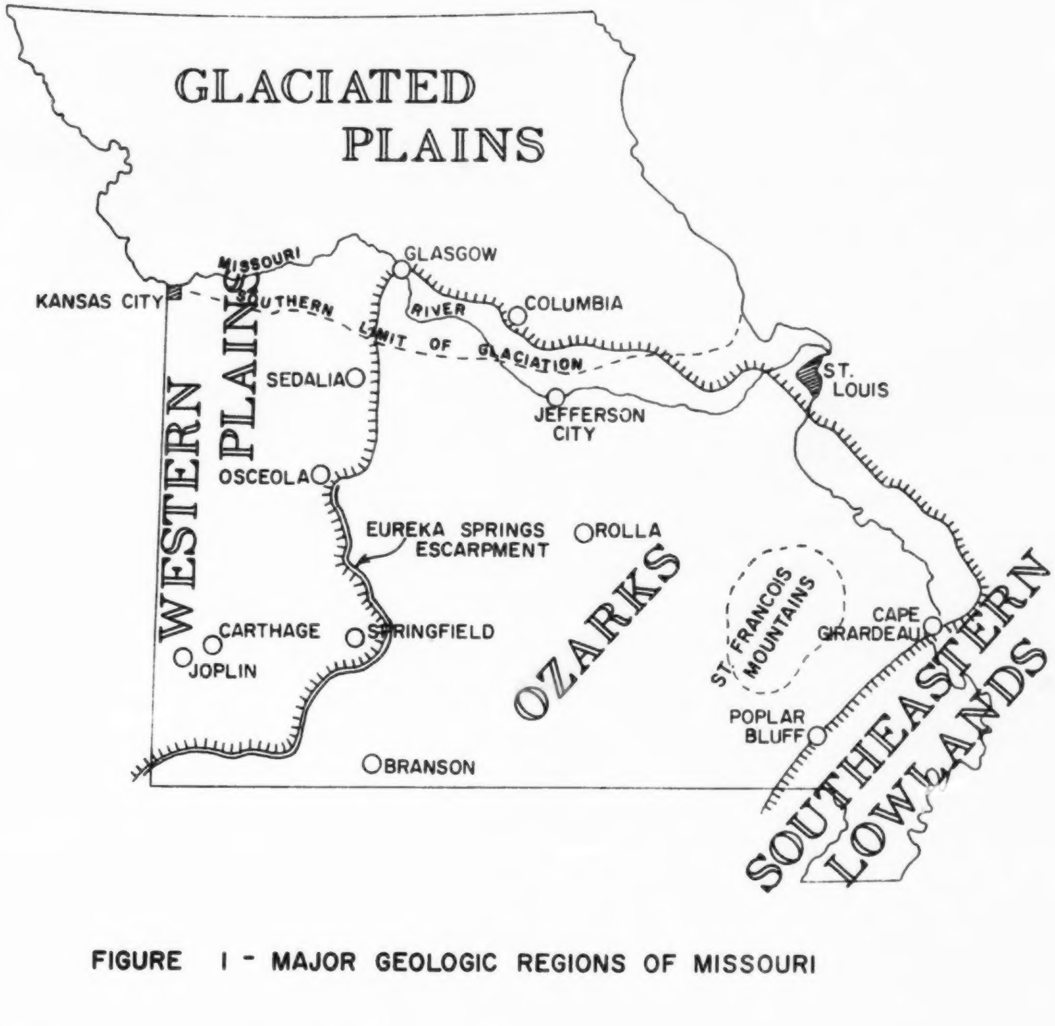
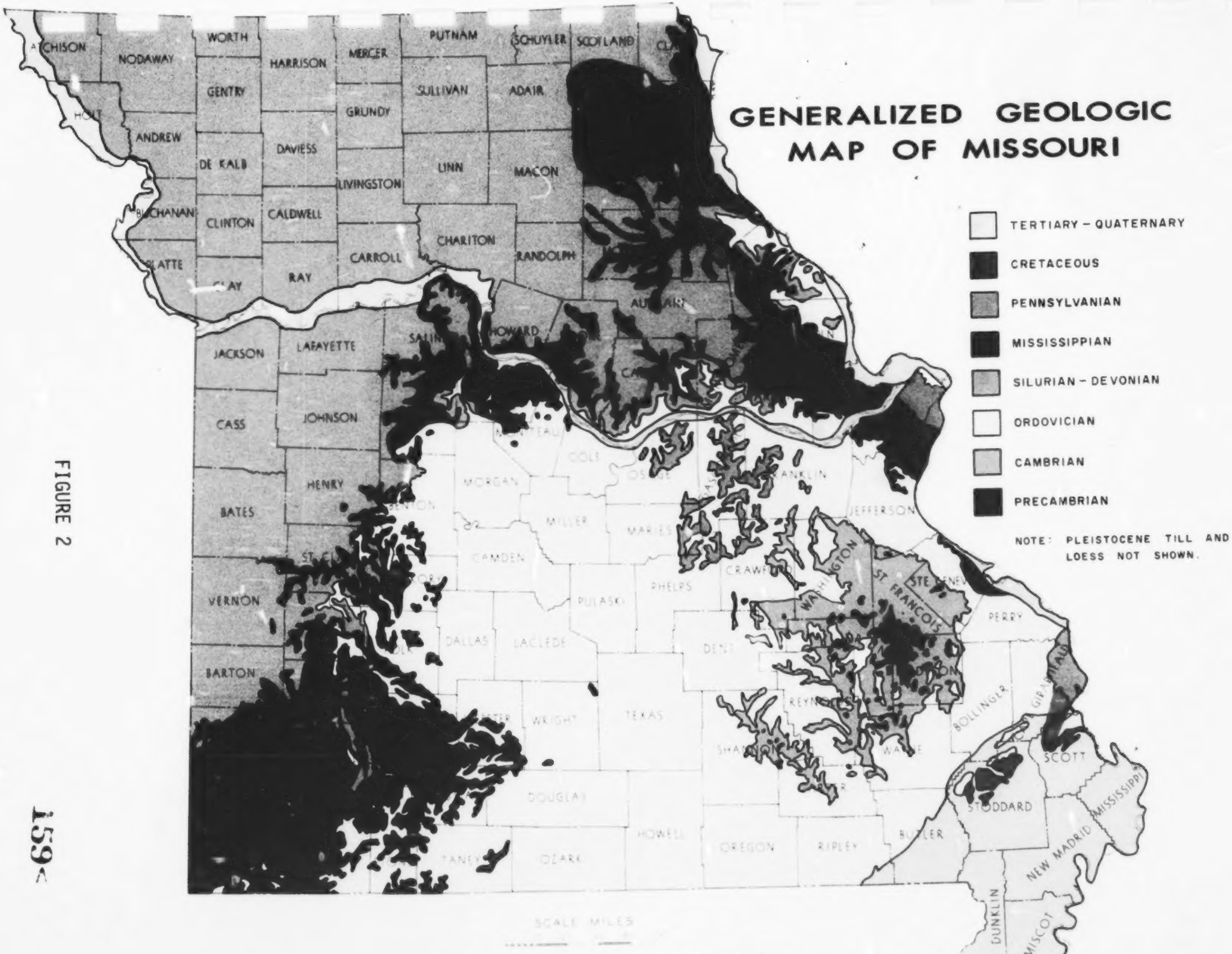

GLACIATED PLAINS
MISSOURI
RIVER
GLASGOW
COLUMBIA
KANSAS CITY
SOUTHERN LIMIT OF GLACIATION
ST. LOUIS
SEDALIA
JEFFERSON CITY
WESTERN PLAINS
OSCEOLA
EUREKA SPRINGS ESCARPMENT
ROLLA
OZARKS
ST. FRANCOIS MOUNTAINS
CAPE GIRARDEAU
CARTHAGE
SPRINGFIELD
JOPLIN
POPLAR BLUFF
BRANSON
SOUTHEASTERN LOWLANDS

FIGURE I - MAJOR GEOLOGIC REGIONS OF MISSOURI


GENERALIZED GEOLOGIC
MAP OF MISSOURI
TERTIARY - QUATERNARY
CRETACEOUS
PENNSYLVANIAN
MISSISSIPPIAN
SILURIAN - DEVONIAN
ORDOVICIAN
CAMBRIAN
PRECAMBRIAN
NOTE: PLEISTOCENE TILL AND LOESS NOT SHOWN.
ATCHISON
NODAWAY
WORTH
HARRISON
MERCER
PUTNAM
SCHUYLER
SCOTLAND
HOLT
ANDREW
GENTRY
GRUNDY
SULLIVAN
ADAIR
DE KALB
DAVIESS
LIVINGSTON
LINN
MACON
BUCHANAN
CLINTON
CALDWELL
CHARITON
RANDOLPH
PLATTE
CLAY
RAY
CARROLL
HOWARD
JACKSON
LAFAYETTE
CASS
JOHNSON
HENRY
BATES
VERNON
BARTON
COLE
MORGAN
MILLER
MARIES
FRANKLIN
JEFFERSON
CAMDEN
PULASKI
PHELPS
WASHINGTON
ST. FRANCOIS
PERRY
DALLAS
LACLEDE
DENT
BOLLINGER
WRIGHT
TEXAS
WAYNE
SCOTT
DOUGLAS
STODDARD
MISSISSIPPI
HOWELL
OREGON
RIPLEY
BUTLER
NEW MADRID
TANEY
OZARK
DUNKLIN
PEMISCOT
SCALE MILES

MISSOURI GEOLOGICAL SURVEY AND WATER RESOURCES
WILLIAM C. HAYES, STATE GEOLOGIST AND DIRECTOR
ROLLA, MISSOURI
1965

FIGURE 2

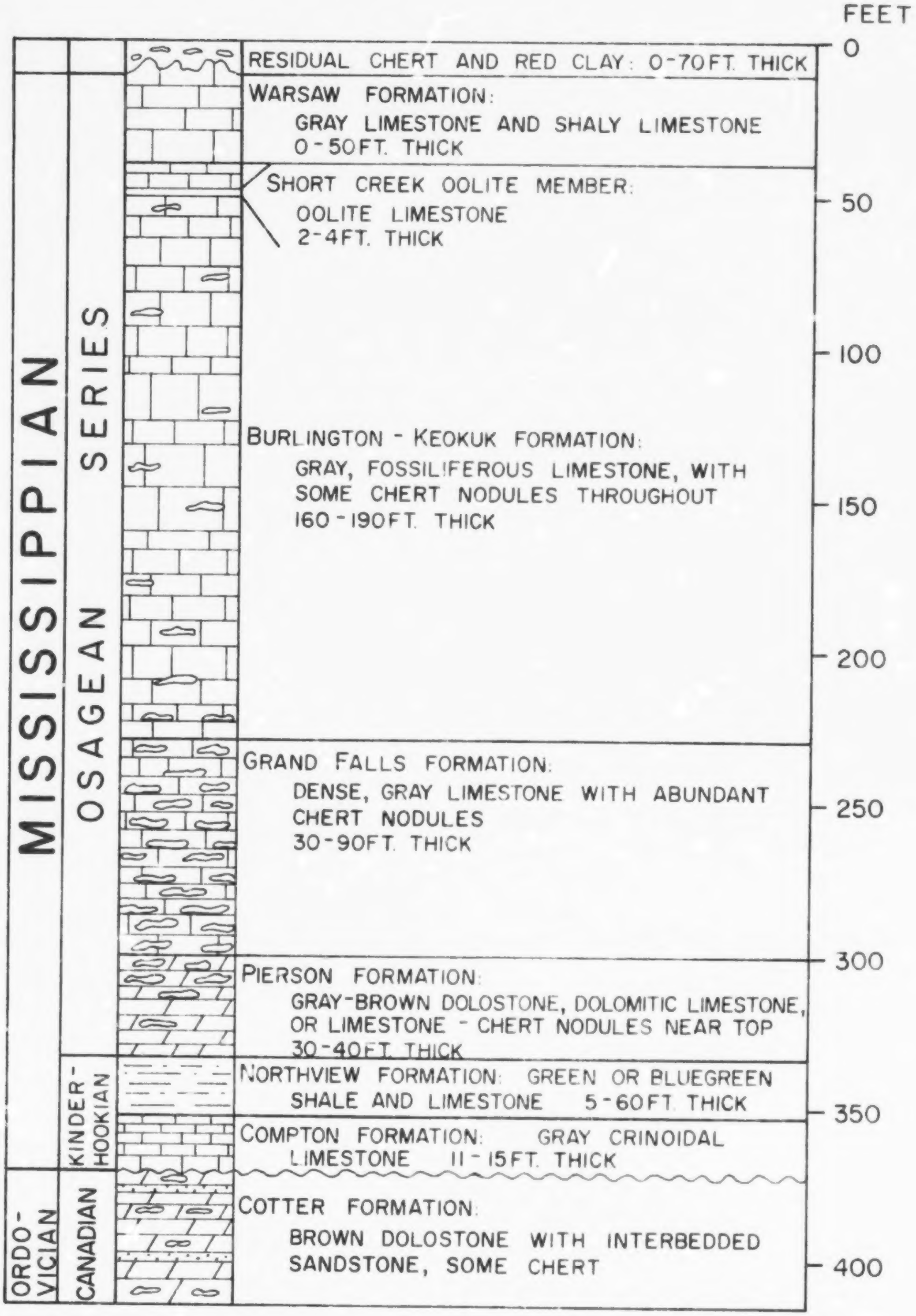

FEET
0
50
100
150
200
250
300
350
400
MISSISSIPPIAN
OSAGEAN SERIES
KINDER-HOOKIAN
ORDO-VICIAN
CANADIAN
RESIDUAL CHERT AND RED CLAY: 0-70FT. THICK
WARSAW FORMATION:
GRAY LIMESTONE AND SHALY LIMESTONE
0-50FT. THICK
SHORT CREEK OOLITE MEMBER:
OOLITE LIMESTONE
2-4FT. THICK
BURLINGTON - KEOKUK FORMATION:
GRAY, FOSSILIFEROUS LIMESTONE, WITH
SOME CHERT NODULES THROUGHOUT
160-190FT. THICK
GRAND FALLS FORMATION:
DENSE, GRAY LIMESTONE WITH ABUNDANT
CHERT NODULES
30-90FT. THICK
PIERSON FORMATION:
GRAY-BROWN DOLOSTONE, DOLOMITIC LIMESTONE,
OR LIMESTONE - CHERT NODULES NEAR TOP
30-40FT. THICK
NORTHVIEW FORMATION: GREEN OR BLUEGREEN
SHALE AND LIMESTONE 5-60FT. THICK
COMPTON FORMATION: GRAY CRINOIDAL
LIMESTONE 11-15FT. THICK
COTTER FORMATION:
BROWN DOLOSTONE WITH INTERBEDDED
SANDSTONE, SOME CHERT

FIGURE 3 - GENERALIZED STRATIGRAPHIC COLUMN OF THE MISSISSIPPIAN SYSTEM AROUND SPRINGFIELD, MISSOURI

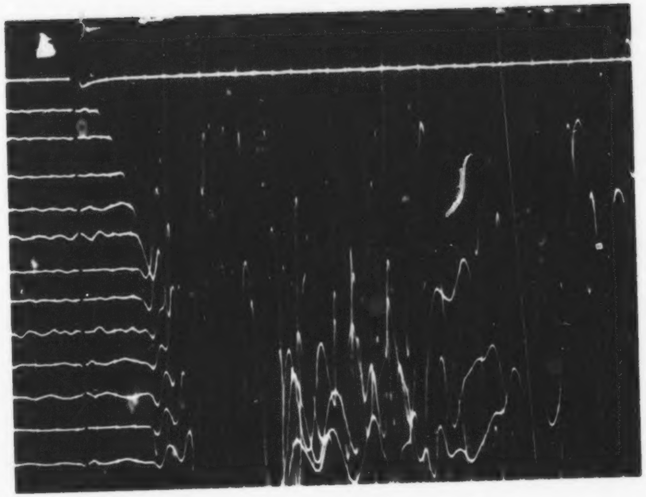
$$V_1 = \frac{15}{.007} = 2140 \text{ FPS}$$

$$V_2 = \frac{30}{.003} = 10{,}000 \text{ FPS}$$

$$V_3 = \frac{15}{.001} = 15{,}000 \text{ FPS}$$

$$D_1 = \frac{dV_1}{2}\sqrt{\frac{V_2-V_1}{V_2+V_1}} = \frac{50}{2}\sqrt{\frac{7860}{12140}} = 20 \text{ FT}$$

$$D_2 = 20 + \frac{55}{2}\sqrt{\frac{V_2-V_1}{V_2+V_1}} = 20 + \frac{55}{2}\sqrt{\frac{5000}{25000}} = 32 \text{ FT}$$



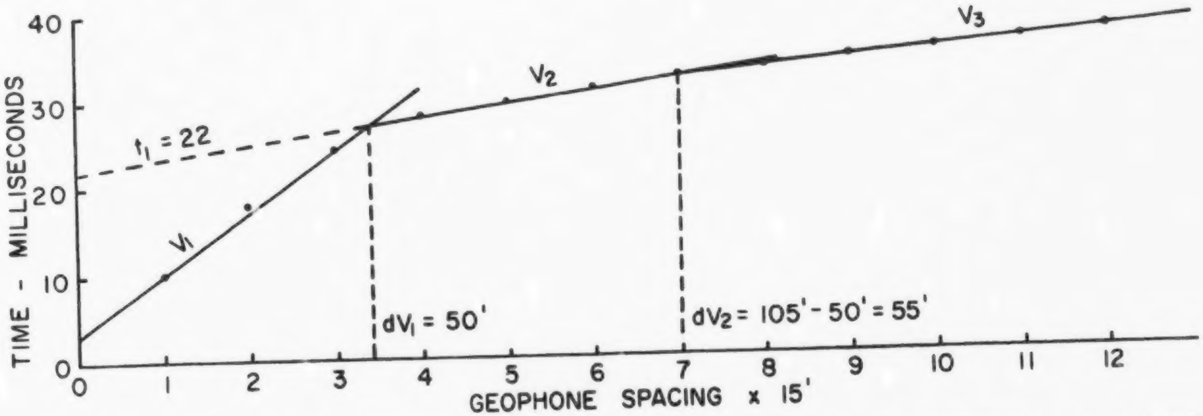
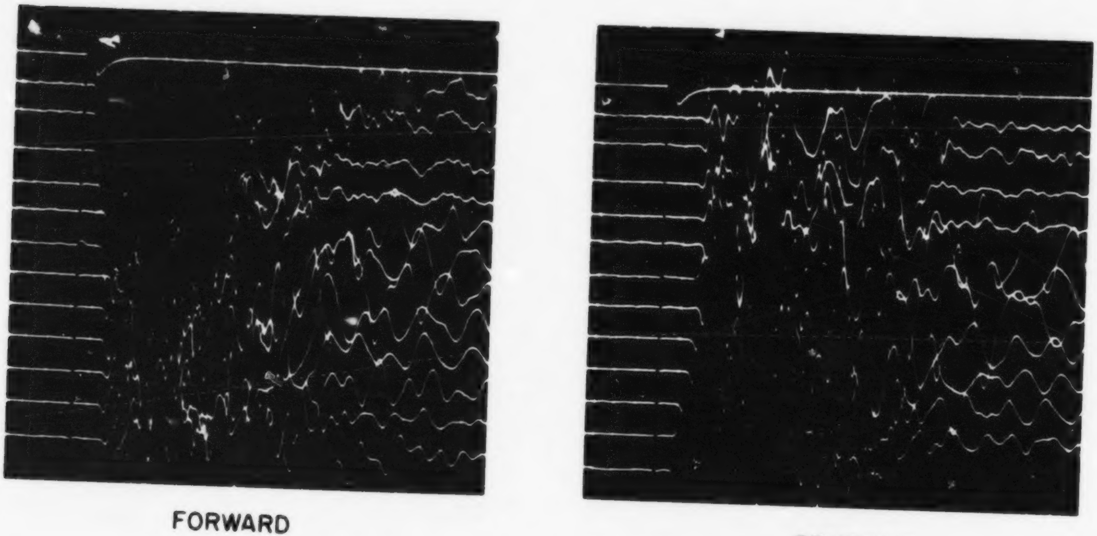


FIGURE 5 - SEISMIC TIME - DISTANCE CURVE - SUBSURFACE LAYER THICKNESS



FORWARD

REVERSE

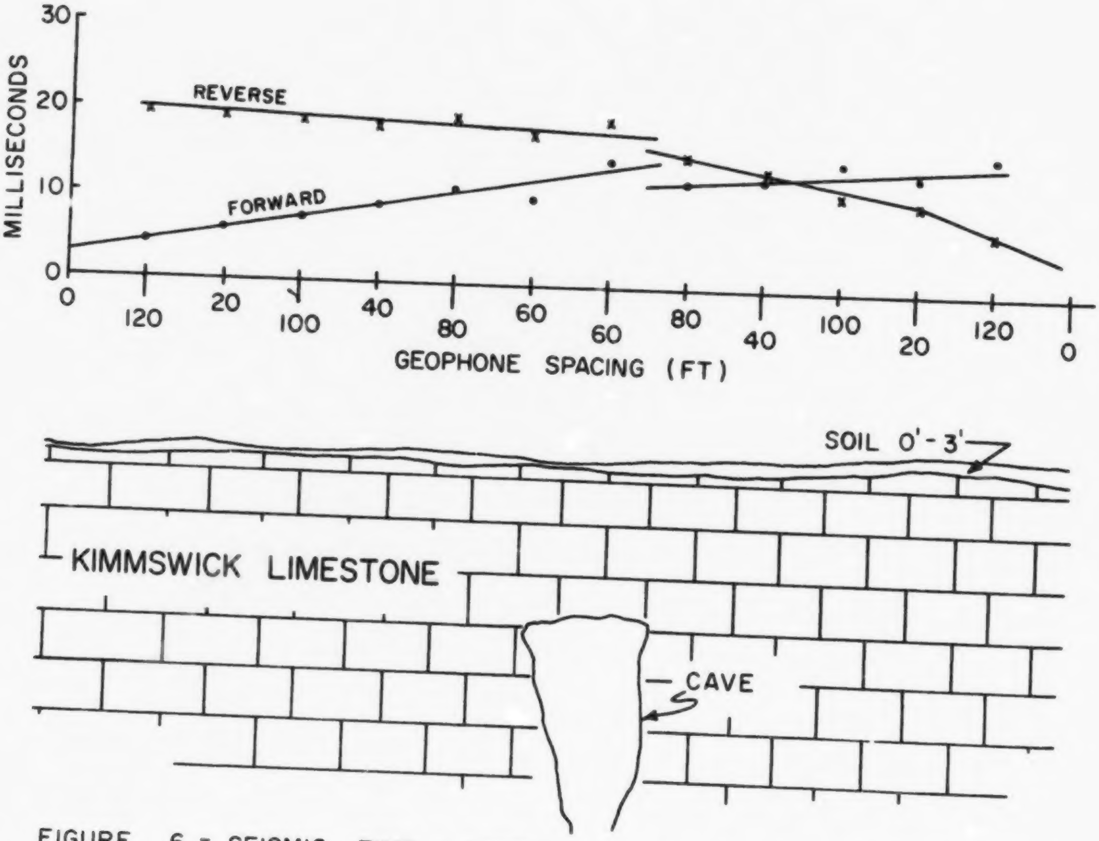
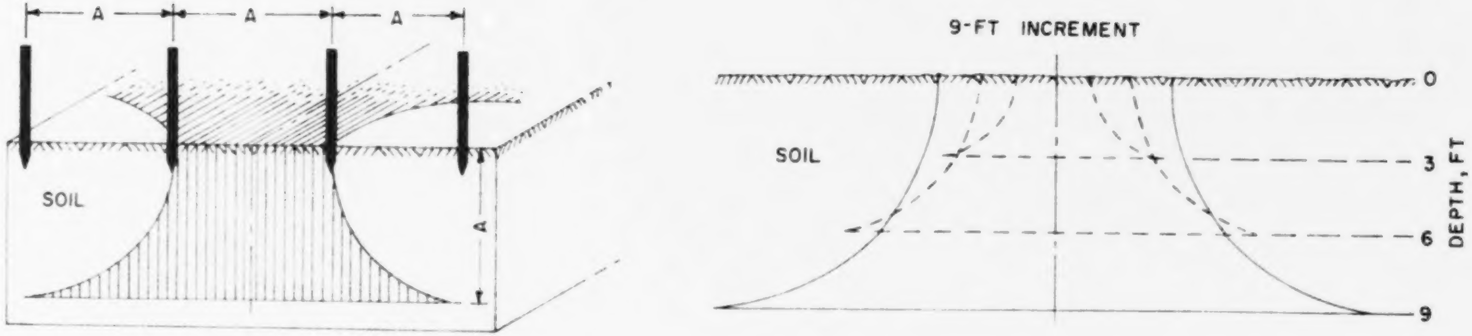
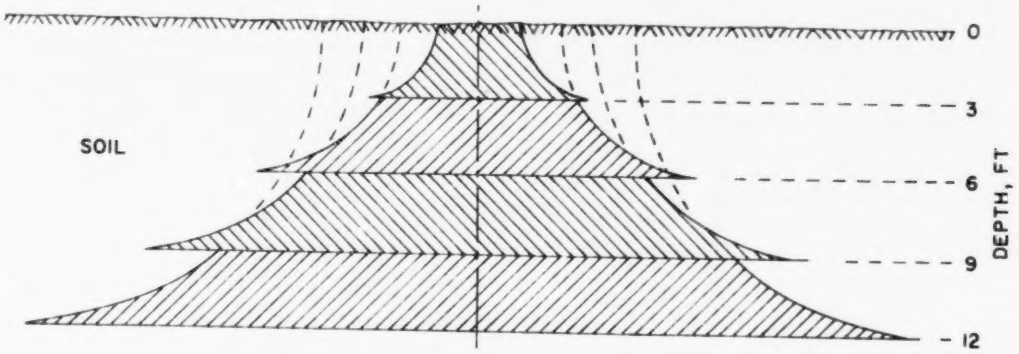


FIGURE 6 - SEISMIC TIME - DISTANCE CURVE - CAVE DETERMINATION

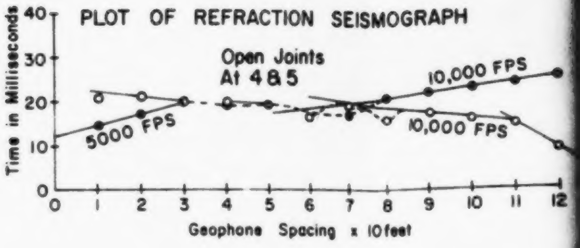

A
A
A
SOIL
A
9-FT INCREMENT
SOIL
0
3
6
9
DEPTH, FT

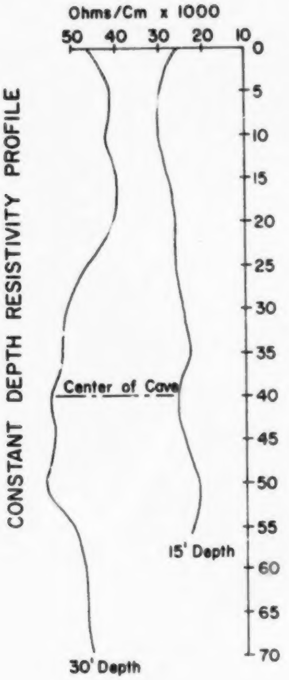
Development of resistivity soundings by increments

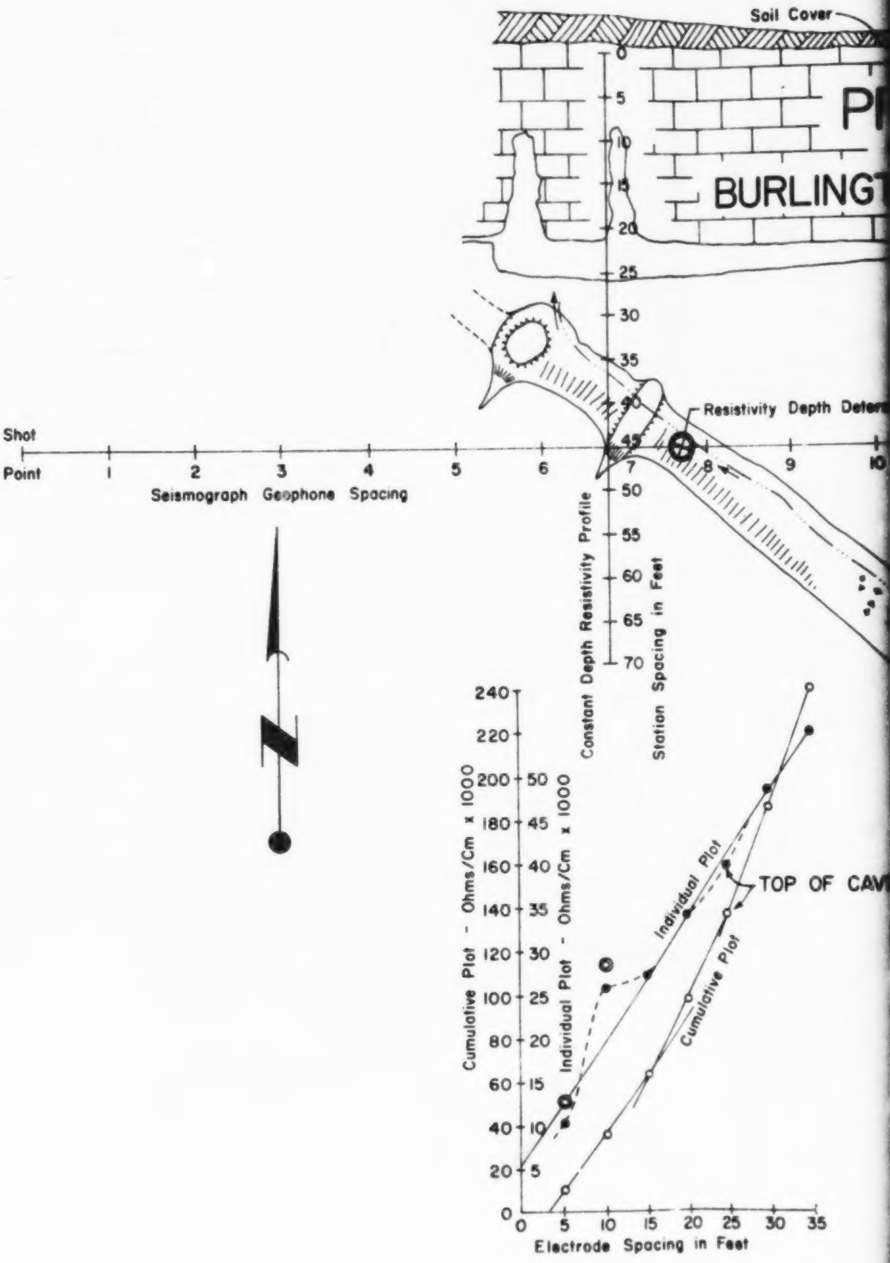

SOIL
0
3
6
9
12
DEPTH, FT

Resistivity of individual layers by increment of depth

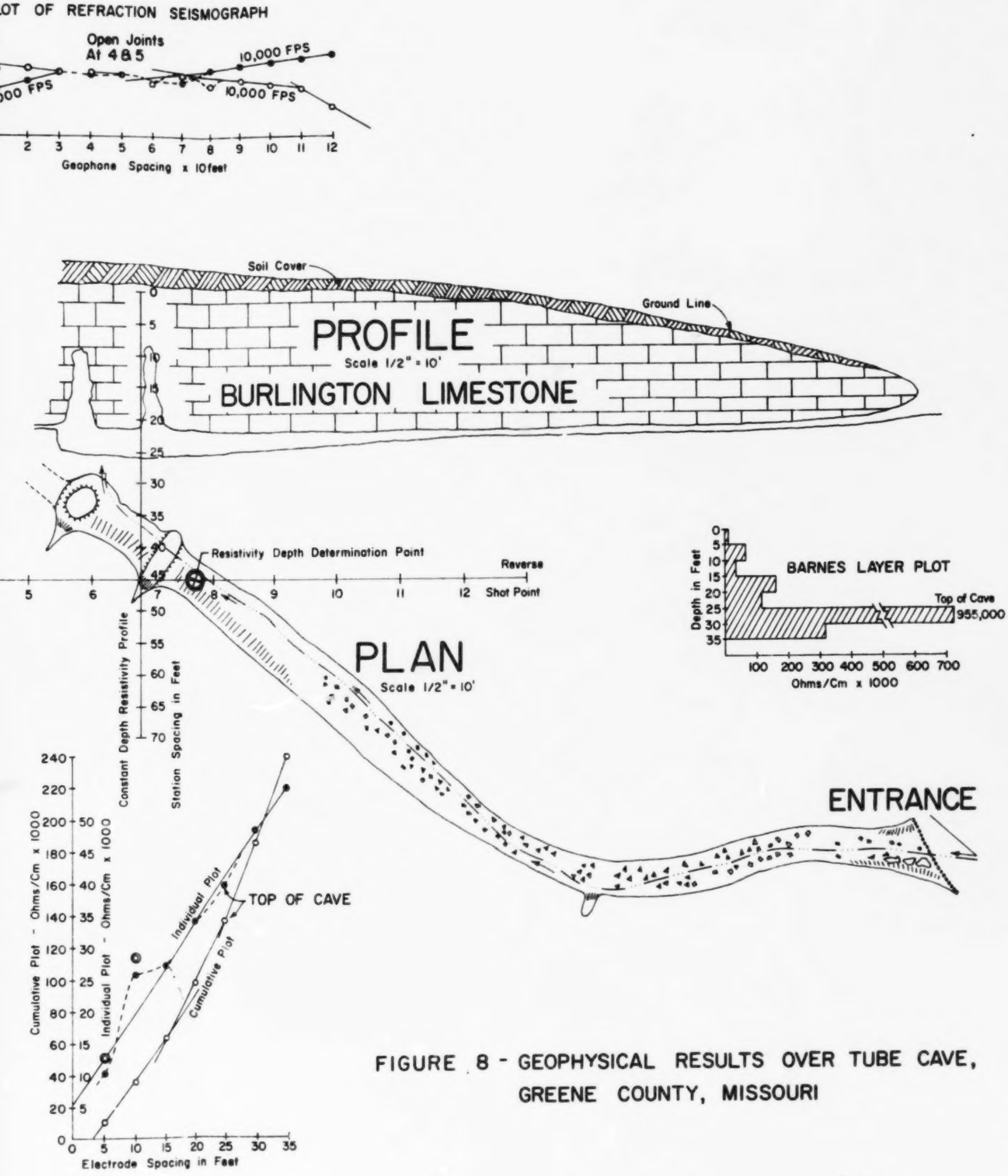
FIGURE 7 - TYPICAL RESISTIVITY SOUNDINGS


PLOT OF REFRACTION SEISMOGRAPH
Time in Milliseconds
40
30
20
10
0
Open Joints
At 4 & 5
10,000 FPS
5000 FPS
10,000 FPS
0 1 2 3 4 5 6 7 8 9 10 11 12
Geophone Spacing x 10 feet


CONSTANT DEPTH RESISTIVITY PROFILE
Ohms/Cm x 1000
50 40 30 20 10
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
Center of Cave
15' Depth
30' Depth


Soil Cover
PI
BURLINGT
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
Resistivity Depth Deter
Shot
Point
1 2 3 4 5 6 7 8 9 10
Seismograph Geophone Spacing
Constant Depth Resistivity Profile
Station Spacing in Feet
240
220
200 50
180 45
160 40
140 35
120 30
100 25
80 20
60 15
40 10
20 5
0
Cumulative Plot - Ohms/Cm x 1000
Individual Plot - Ohms/Cm x 1000
Individual Plot
Cumulative Plot
TOP OF CAV
0 5 10 15 20 25 30 35
Electrode Spacing in Feet

A



LOT OF REFRACTION SEISMOGRAPH
Open Joints At 4 & 5
10,000 FPS
000 FPS
10,000 FPS
2 3 4 5 6 7 8 9 10 11 12
Geophone Spacing x 10 feet
Soil Cover
Ground Line
PROFILE
Scale 1/2" = 10'
BURLINGTON LIMESTONE
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70
Constant Depth Resistivity Profile
Station Spacing in Feet
Resistivity Depth Determination Point
5 6 7 8 9 10 11 12
Reverse Shot Point
PLAN
Scale 1/2" = 10'
ENTRANCE
BARNES LAYER PLOT
Depth in Feet
0 5 10 15 20 25 30 35
Top of Cave
955,000
100 200 300 400 500 600 700
Ohms/Cm x 1000
240 220 200 180 160 140 120 100 80 60 40 20 0
Cumulative Plot - Ohms/Cm x 1000
50 45 40 35 30 25 20 15 10 5
Individual Plot - Ohms/Cm x 1000
Individual Plot
Cumulative Plot
TOP OF CAVE
0 5 10 15 20 25 30 35
Electrode Spacing in Feet

FIGURE 8 - GEOPHYSICAL RESULTS OVER TUBE CAVE, GREENE COUNTY, MISSOURI

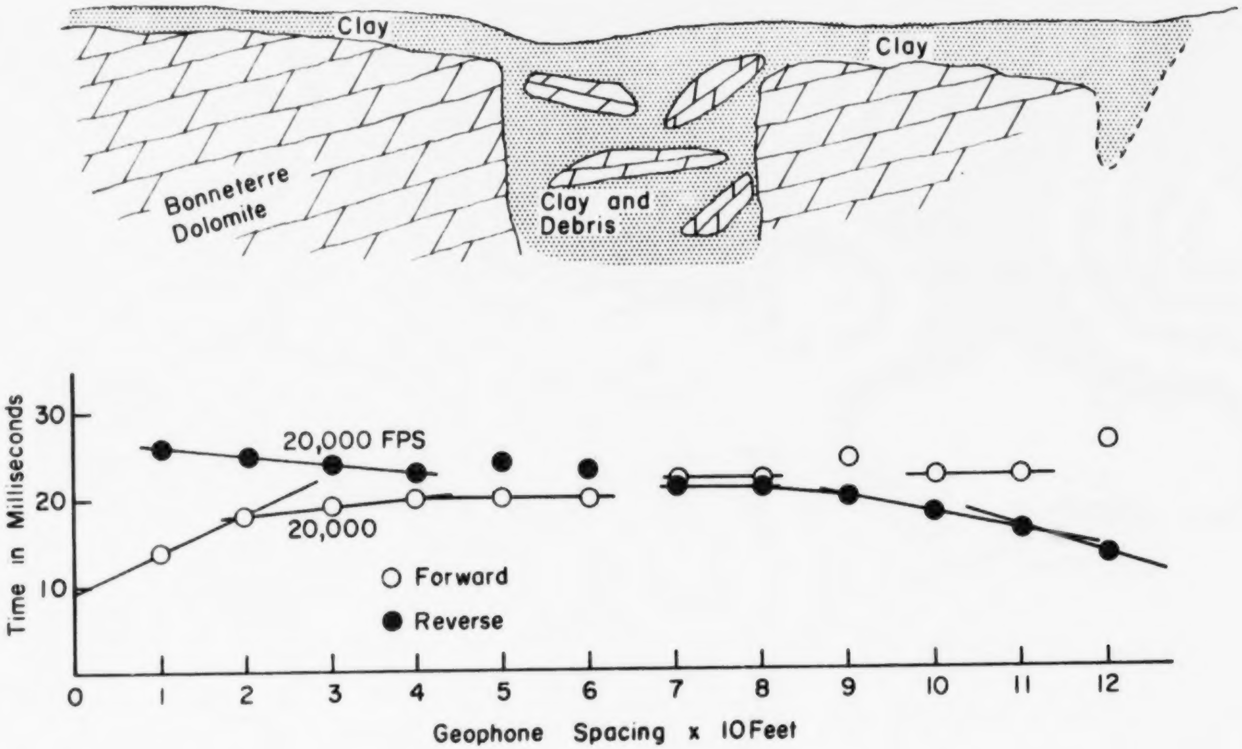


FIGURE 9A - SEISMIC RECORD - ENLARGED JOINT TO THE SURFACE

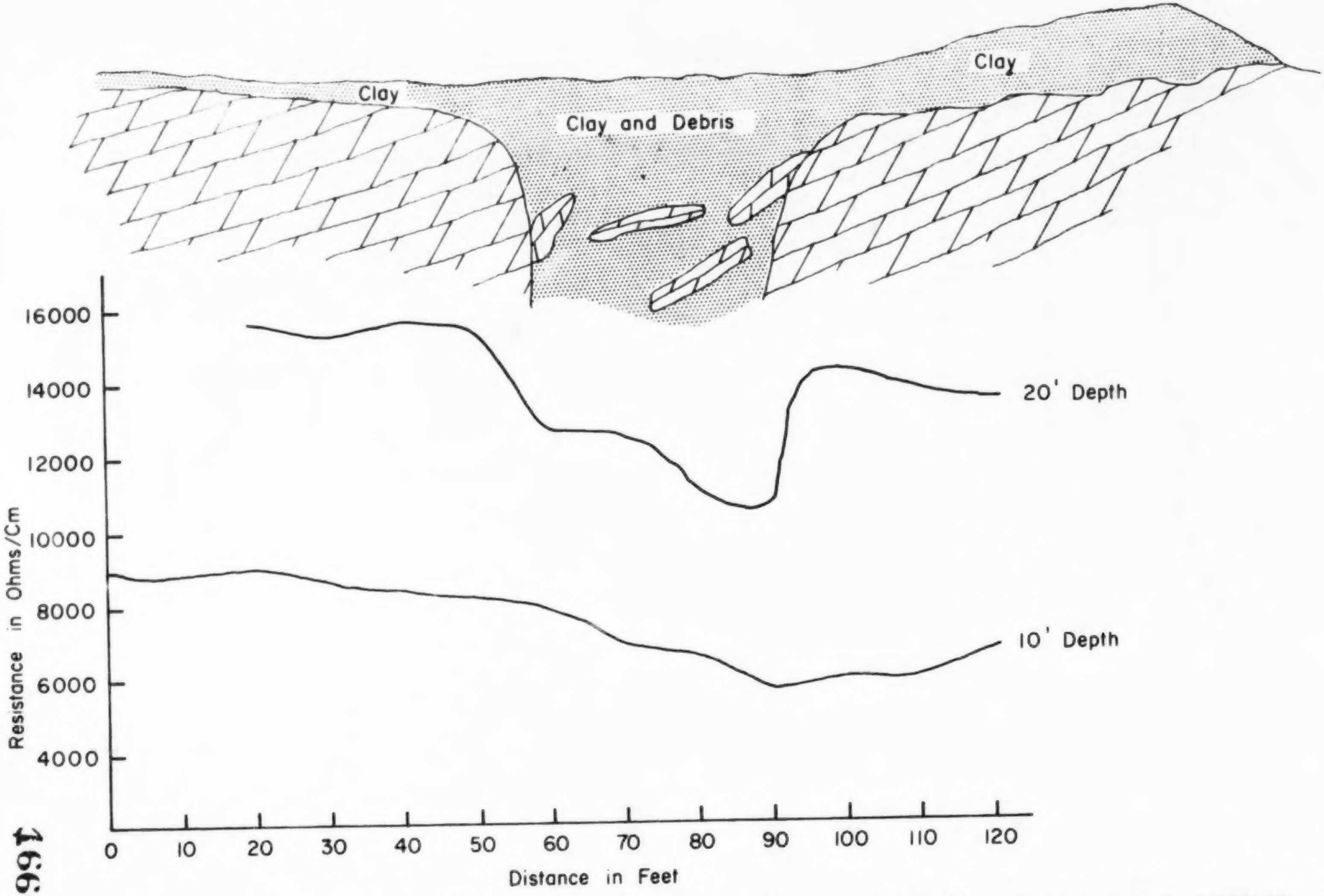


FIGURE 9B - CONSTANT DEPTH - RESISTIVITY PROFILE - ENLARGED JOINT TO THE SURFACE

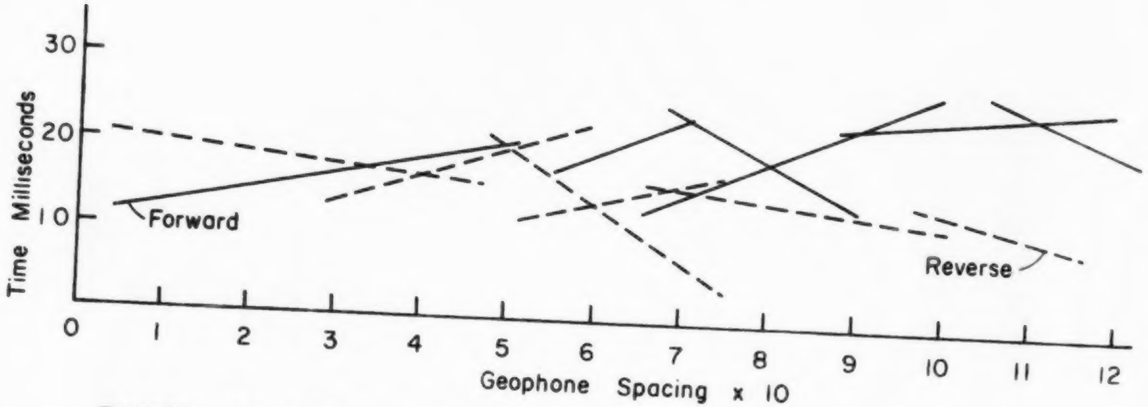


FIGURE 10A - SEISMIC RECORD OVER PINNACLED BEDROCK

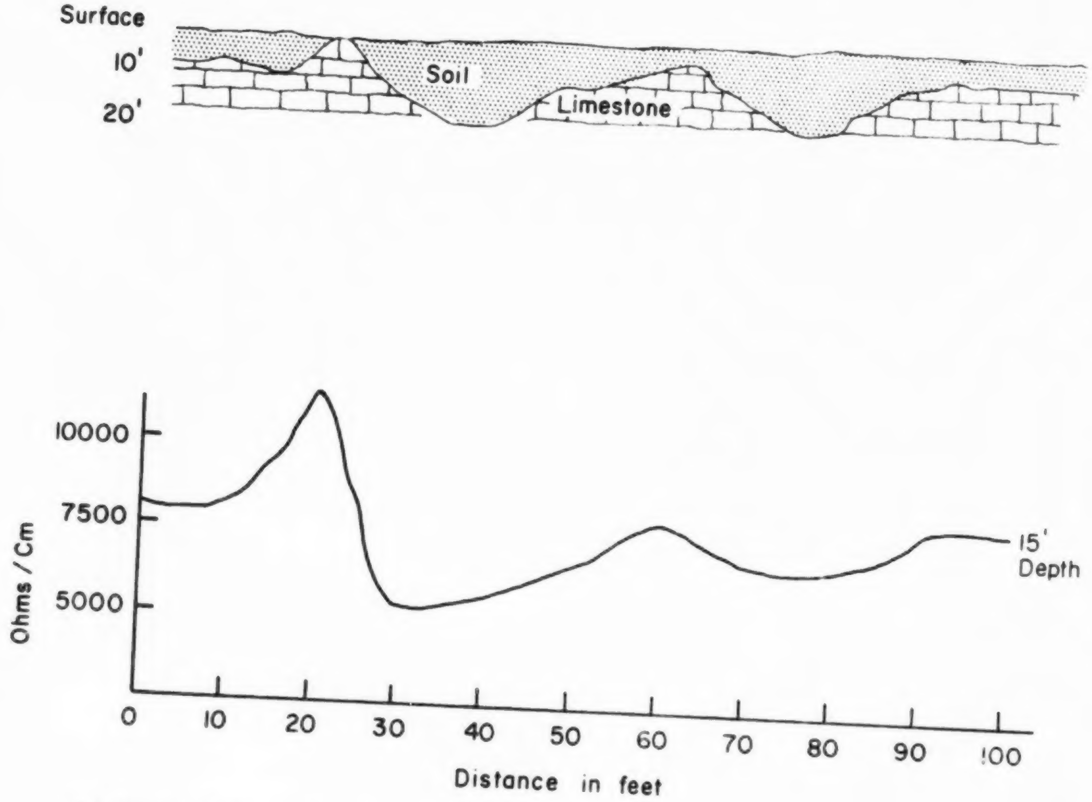


FIGURE 10B - CONSTANT DEPTH - RESISTIVITY PROFILE OVER PINNACLED ROCK

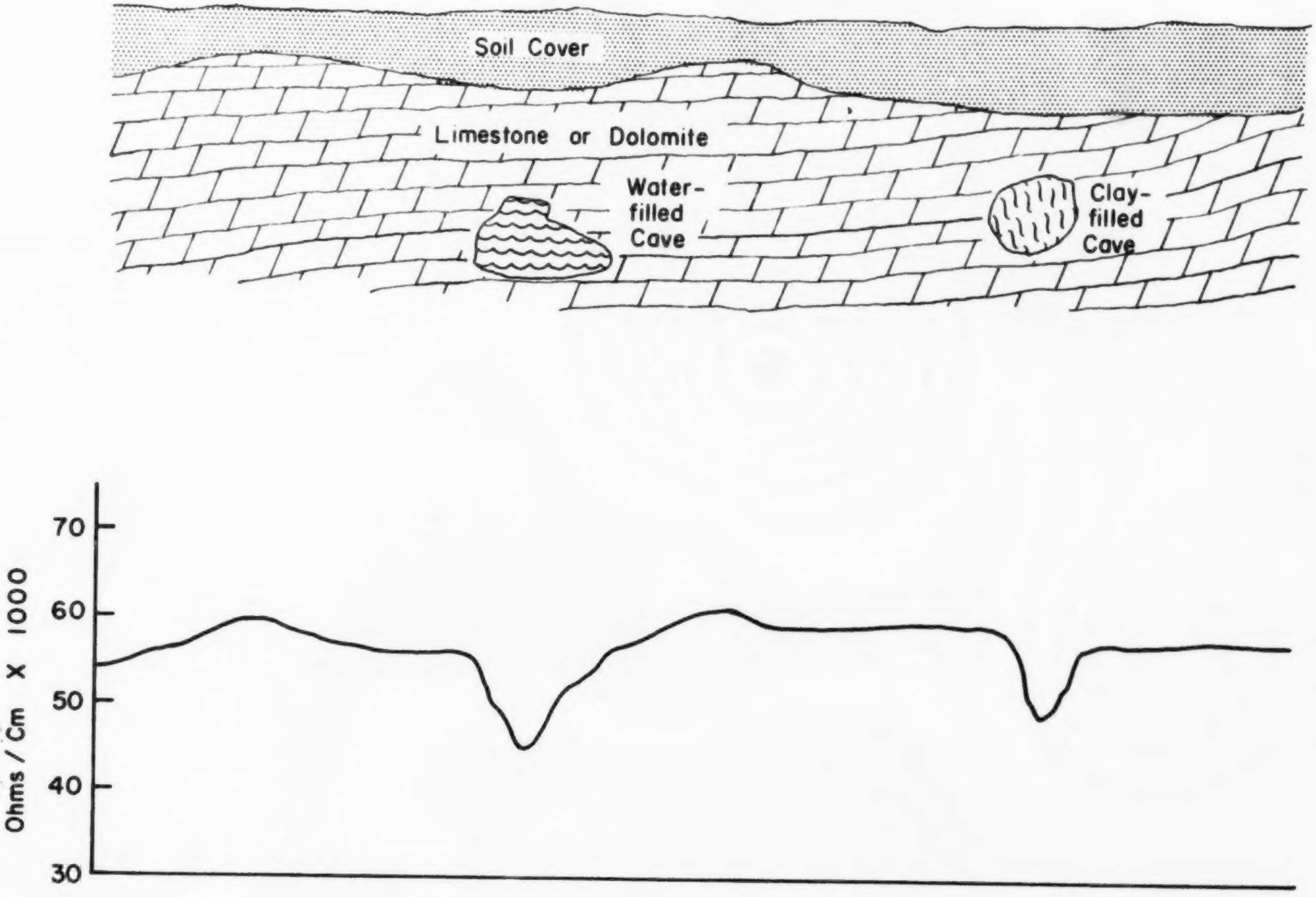

Soil Cover
Limestone or Dolomite
Water-filled Cave
Clay-filled Cave
70
60
50
40
30
Ohms / Cm X 1000

FIGURE 11 - TYPICAL CONSTANT DEPTH - RESISTIVITY PROFILE OVER WATER OR CLAY FILLED CAVES